Biomechanical Variations in Gait of Active

And

Sedentary Individuals upon Perceived Exertion

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A Dissertation Presented to the Faculty of Health Sciences of the University of Malta in Part Fulfilment of the Requirements for the Degree of Masters of Science (by Research) in Clinical Biomechanics at the University of Malta

Abstract

Aim: The aim of this research was to investigate whether there are comparable differences in the gait kinematic, kinetic and spatio-temporal parameters which can be observed within the gait of both active and sedentary young adults upon exertion up to the point of maximal fatigue.

Method: The current study is a quantitative, correlational, experimental study. The entire research protocol was performed in a clinical gait and motion analysis laboratory in the Podiatry Department, within the Faculty of Health Sciences (University of Malta, Mater Dei Hospital). An 18-camera Vicon Motion Capture System was utilised to collect all gait parameters. Retroreflective markers were placed upon various anatomical locations on the participants' lower limbs as dictated by the Plugin-Gait model (Vicon). This system provided a digital map of the participants' walking pattern in space whilst also providing quantifiable data which was then used to measure pattern differences. All participants were asked the same questions and the same readings were taken throughout the entire research process. After the initial motion capture, participants were asked to run/jog on a treadmill at a self-selected, comfortable pace whilst having their relevant recordings of Rate of Perceived Exertion (RPE), speed, distance, time, peripheral oxygen saturation (SPO_2), and Heart Rate (HR) recorded. Once fatigue was achieved (when the participants stated that they scored their fatigue as 20 on the RPE scale), the participants were required to perform one final motion capture with the same instructions as the earlier gait analysis procedure. Subsequently, the six best pre- and post- trials (three for pre- and three for post-) with the most representative gait patterns were selected from each session and used for data processing. In data processing, the captures were tabulated and an average was calculated. This entire process was conducted for all participants and spanned over a period of 6 months.

Results: A total of forty healthy participants successfully participated in this study, (Active participants: 31; Sedentary participants: 9; Male Participants: 20; Female Participants: 20; Age average: 26; SD ± 2.05). Significant ($p < 0.05$) fatigue-induced changes in ankle dorsi/plantarflexion and GRFZ occurred in all the five phases of gait (Heel Strike, Mid-Stance, Weight-Transference, Toe-off, and Mid-Swing). This study found that these kinematic and kinetic variations altered various spatio-temporal parameters. These variations were evident in all the participants' reduction in cadence ($p = 0.002$), step times ($p < 0.001$) and stride times (p = 0.012). Furthermore, this study observed that fatigue alters gait significantly regardless of whether participants are active or sedentary.

Conclusion: Considering the nature of the fatiguing task, subjects experienced maximal exhaustion, but they may not have progressed through to maximal fatigue. Nevertheless, the readings obtained within this study, which could be described as a "fatigued/exhaustive state", still satisfy the requirements of the aim. Furthermore, this research observed significant effect of fatigue on ankle kinematic and kinetic mechanisms. Ankle dorsi/plantarflexion, GRFZ, along with other (less-significant) biomechanical alterations led to significant reduction in cadence, step times and stride times. It was also discussed how these kinematic and kinetic paradigms have substantial implications for the gait pattern of athletes, the elderly, and the general population. Addressing these may decrease the risk of falls and injuries.

Keywords: Fatigue, exercise tolerance, cadence, gait, RPE, Vicon Motion Capture

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Acknowledgments

I would like to thank my supervisors Prof. A. Gatt and Mr D. Sillato for all the help and guidance which they provided throughout this research study.

I would also like to thank my parents and Janine for their invaluable and unwavering support.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

- ADLs: Activities of Daily Living
- ASIS: Anterior Superior Iliac Spine
- BPM: Beats per minute
- CFS: Chronic Fatigue Syndrome
- CNS: Central Nervous System
- EMG: Electromyography
- FOR: functional over-reaching
- FREC: Faculty Research Ethics Committee
- GDPR: General Data Protection Regulation
- GRF: Ground Reaction Force
- HCO_3^-: Bicarbonate
- HIT: High Intensity Training
- HR: Heart Rate
- HRV: Heart Rate Variability
- ME: Myalgic Encephalomyelitis
- MPF: Mean Power Frequency
- NFOR: Non-Functional Over-Reaching
- OT: Overtraining
- PiG: Plug-in Gait
- PSIS: Posterior Superior Iliac Spine
- QOL: Quality of Life
- RPE: Rate of Perceived Exertion
- SD: Standard Deviation
- SPO_2: Peripheral Oxygen Saturation
- UREC: University of Malta's Research Ethics Committee
- WMSD: Work-related Musculoskeletal Disorders

Chapter 1: Introduction

1.1. Research Question

What are the kinematic and kinetic manifestations of fatigue in adults with varying levels of daily activity?

1.2. Background to the research problem

Fatigue is a phenomenon which brings about physiological, psychological and biomechanical changes in the body. Fatigue can be a powerful unit of measure to assess one's physical capabilities and limitations to enhance one's own active lifestyle. Then again, if handled poorly, fatigue can be a detrimental experience which can pre-dispose an individual to physical and psychological injuries. Although gait is a daily activity which is often performed at a subconscious level, if implemented within an exercise regime, gait can become a fatiguing task. This research aims to observe gait and the biomechanical effects that fatigue has upon gait.

Fatigue is generally synonymous with tiredness and the inability to carry out a physically strenuous activity in view of one's own physical limitations. Sharpe & Wilks (2002) explain this by outlining the difference between weakness and fatigue by stating that weakness is 'a diminished ability' of a muscle at rest to exert a significant maximal contraction, whilst fatigue is the loss of maximal force-generating capacity in view of repetitive muscular activity. Fatigue can be caused by extreme physical exertion or even simple day-to-day activities. Fatigue is further described as "any exercise-induced reduction in the maximal capacity to generate force or power output" (Karvekar, 2019). The location of fatigue depends upon the exercise being performed and the muscles being used. Therefore, to understand fatigue, first one must understand the physiology of movement.

Globally, 20% of males and 30% of women feel frequent weariness. Cella et al. (2002) found that 55% of healthy people reported physical exhaustion, 21% reported affective fatigue, and 24% reported cognitive fatigue. These different types of fatigues were then classified under the umbrella-term "Healthy Fatigue" (Cella, et al., 2002).

- **Biomechanical fatigue**: Fatigue can lower athletic performance, increase injury risk, and prolong recovery. Prolonged and vigorous physical exercise can induce muscle tiredness, which impairs coordination, reaction time, and increases the risk of falls and accidents (Charest & Grandner, 2022).
- **Cardiovascular fatigue**: This occurs when prolonged or intensive physical activity tires the heart and blood arteries. Athletes' endurance, pulse rate, and blood pressure can be hampered by this sort of weariness.
- **Mental weariness (or cognitive fatigue)**: Cognitive fatigue impairs decision-making, concentration, and motivation, all of which reduce performance. In the article by Charest and Grandner, (2022), it was discussed that sleep health improves sports performance. Insufficient sleep length, quality, daytime lethargy and exhaustion, suboptimal/irregular sleep schedules, and sleep and circadian disorders are common in athletes.
- **Psychological tiredness**: Fatigue-related occupational injuries and illnesses can raise healthcare expenses and lower productivity, affecting the person's economic output. Fatigue increases absenteeism and the risks of occupational accidents and injuries (Karvekar, 2019). Psychological exhaustion develops when an athlete or worker is stressed or has done mentally demanding duties for a long time. Fatigued personnel make more mistakes, have poor judgement, and react slowly, increasing the chance of accidents and errors. Workplace accidents increase work-related musculoskeletal diseases (WMSDs). According to Hosseini et al., (2021), repetitive strain injuries are the most prevalent work-related health issues and fatigue causes. The authors expand further by stating that fatigue caused 29% of US job injuries.
- **Chronic Fatigue Syndrome**: Patients with increased fatigability without a medical cause are diagnosed with chronic fatigue syndrome (CFS). Chronic fatigue lasting over six months is its hallmark. PEM (post-exertional malaise), unrefreshing sleep, cognitive impairment, autonomic dysfunction, and muscular or joint pain are symptoms. CFS lowers health-related quality of life. Twenty-five to twenty-nine per cent of CFS patients are housebound or bedridden, more than half are unemployed, and only 19% work full-time. In affluent nations, chronic fatigue symptoms are very common, according to Lewis and Wessely (1992). Men had 14.3% weariness and women 20.4%

(Lewis & Wessely, 1992). Rheumatoid arthritis affects 1% of the global population, or 17 to 24 million people. Without an objective diagnostic tool, prevalence estimates are challenging (Lim, et al., 2020). Athletes and workers worldwide might be harmed by chronic fatigue.

In the current research, Biomechanical and Cardiovascular fatigue are the two main types of fatigue which will be observed, whilst Cognitive, Psychological, and Chronic Fatigue Syndrome are not examined in the current study.

1.2.1. Physiology of movement

Understanding the physiology of mechanical movement will shed light on the causes and effects of fatigue. Any movement done by our body is generated by forces elicited by electrical action potentials produced by the central nervous system (CNS). These action potentials are carried through motor neurons into the muscle fibres whereby they will excite the muscle into action. The complex, or site, where motor neurons, neuromuscular junctions and muscle fibres convene, form what is a called a motor unit.

1.2.2. Physiology of Muscle Contraction

Physiologically, during the maximal contraction of a muscle, all the motor units of the said muscle are being activated. This maximal contraction allows for a faster rate of fatigue as Type-2 muscle fibres are recruited. On the other hand, during sub-maximal contractions of a muscle Type-I fibres are recruited, which allow for a more gradual and a slower-rate of fatigue (Karvekar, 2019).

1.2.3. Physiology of Fatigue

Fatigue is the inability of an individual to perform a task due to exertion. At the sarcomere level, fatigue is defined as the inability of a muscle to maintain or perform a contraction, thus stimulation of said muscle is inhibited. Usually, a muscle would be unable to perform a contraction because of an increase in the activation threshold of the muscle being stimulated. According to Burnley and Jones, (2016), this phenomenon is in turn influenced by the intensity of the exercise being performed (Burnley & Jones, 2016). Examples of causes for the reduction in muscular synaptic activation include:

- A reduction in the will for the exercise (usually in the moderate exercise intensity domain; e.g. extremely prolonged exercise);
- Depletion of muscular fuel reserves (during heavy-intensity exercise);
- Accumulation of fatigue-inducing metabolites (during severe-intensity exercise).

Neuromuscular fatigue can be overcome, but the intensity with which it can be overcome depends on the health, age, and familiarity with exercise (pain tolerance/motivation to exercise) of the person. The study goes on to describe that true fatigue was only achieved, within the confines of the study, by young healthy and motivated participants who performed until reaching task failure. True fatigue could not be overcome by any additional (internal or external) motivation or coercion. Burnley & Jones, (2016), described this as purely 'physical' and it could only be understood through bioenergetic, muscle metabolite/substrate, and neuromuscular considerations (Burnley & Jones, 2016).

1.2.4. Fatigue monitoring and perceived exertion

Two main types of fatigue-measuring techniques are:

- External load quantifying and monitoring tools (i.e. power output measuring devices, time-motion analysis). External load can be defined as the work completed by the athlete.
- Internal load unit measures (i.e. perception of effort, heart rate, blood lactate, and training impulse). Internal load is the relative physiological and psychological stress imposed.

Both external and internal loads have merit for understanding the athlete's training load, a combination of both may be important for training monitoring. Indeed, it may be the relationship between external and internal loads that may aid in revealing fatigue (Halson, 2014).

1.2.5. Fatigue and biomechanics of gait

As stipulated in the previous section outlining the physiology of fatigue and motor-firing, electric signals change their frequency and intensity as a result of the physical fatigue induced by movement. The study by Yoshino, et al., (2004), outlines details of how, for example, the mean power frequency (MPF) of an electromyography (EMG) signal is known to be shifted downward by the muscle fatigue. Muscle fatigue within this scenario can be induced by static isometric contraction and by dynamic movements such as running, cycling, and skiing (Yoshino, et al., 2004). What they found in their study is that fatigued subjects walked slower, with higher stride-to-stride variability and increased local dynamic stability (Yoshino, et al., 2004). This was in view of the fact that the participants subconsciously started widening their base-of-support during gait as they became more exhausted and slower. This phenomenon is quite synonymous with the results of other researches like the one of Ko et al., (2010), Helbostad, et al., (2007), and Hills, et al., (2001). Many of the aforementioned authors agree that this phenomenon should be associated with an automatic fall-prevention mechanism. Helbostad, et al., (2007), stated that their participants, when fatigued, increased step width and trunk acceleration gradient. So apart from adopting a broader base of support, participants increased their lateral weight shift during gait (Helbostad, et al., 2007). The authors went on to explain that to maintain a stable gait, the body's centre of mass is required to be within the boundaries of the supporting foot and where the next foot hits the ground. Helbostad, et al., (2007) and Yoshino, et al., (2004), stated in their research that the majority of alterations in gait happened mainly at the ankle/foot complex.

1.2.6. Sedentary vs Active lifestyle

Physical activity has been defined as being any movement that requires more energy expenditure than when a person is at rest (Torbeyns, et al., 2014). Maintaining a physically active lifestyle would predispose a long and high-quality life. Furthermore, there are physiological benefits when maintaining an active lifestyle. Brain plasticity was found to be affected by such a lifestyle. Neurogenerative, neuroadaptive and neuroprotective systems are stimulated. These aid in cognitive and motor learning (Torbeyns, et al., 2014).

Contrastingly, a sedentary activity has been defined as any waking activity which utilises the same energy expenditure required for a sitting or reclining posture (Torbeyns, et al., 2014). In today's mechanised and automated society, there are less demands for physical activity to conduct work/leisure/daily routines. Occupations nowadays tend to have a sedentary component. Research conducted via surveys have outlined that television viewing, computer use and electronic games have become the most preferred leisure activities of modern persons. Other studies have outlined that a common reason that is given for not being physically active is a lack of time (Torbeyns, et al., 2014).

As mentioned before, there are significant differences between the effects of fatigue on the gait of the sedentary and those of the active individual. Yoshino, et al., (2004), delved into this phenomenon within their study and concluded that after a 3-hour exercise session, the active individuals did not show any significant physiological or muscular fatigue, unlike their sedentary counterparts (Yoshino, et al., 2004). Puetz, et al., (2008), outline within their study that persistent fatigue due to physical inactivity affects 20% of the adults in the community worldwide. Within their study, Puetz, et al., (2008), stated that after introducing a training programme to sedentary individuals with well-defined medical conditions, the participants reported a reduction in fatigue. The authors go on to explain that an aerobic training programme was found to be ideal for improving the participants' quality of life (Puetz, et al., 2008).

To conclude, in order for this study to assess gait and gait-induced fatigue, an understanding of gait biomechanics is paramount. Gait biomechanics, through the use of a gait analysis systems (observational/video/instrumented gait analysis), permits this research to understand gait kinematics and kinetics. Gait kinetics delves into the forces and moments that result in the movement direction of an individual's gait, but most especially it focuses on the varying GRFs on the foot. This can be observed via force plate systems which are stationary devices that record this phenomenon when walked upon (Leusmann, et al., 2011).

1.3. Statement of research problem

Following a thorough review of the research, there seems to be insufficient evidence on the effects of fatigue on the gait pattern of the individual. Available literature on the effects of fatigue on gait was found to be targeted at specific population groups, be it athletic, elderly or obese individuals. Although valid within their specific niches, these studies do not address individuals who do not fall within the aforementioned categories. Furthermore, there are contradictory views and conclusions about the manifestations of fatigue on gait within the available literature. The current research aims to address these contradictions, by providing a holistic view and a guide to this phenomenon. Within the clinical environment, healthcare providers would benefit from a guide of the physical manifestations of fatigue as this would contribute to an increase in patient safety and confidence. Furthermore, the current research aims to shed light on the effects of fatigue on gait by quantifying and objectifying, in biomechanical terms, the changes in gait after a workout by the healthy individual. It will help the clinician to differentiate between a person's fatigued gait pattern and a normal (unfatigued) gait pattern. Employers would benefit from this research as knowledge about fatigue would promote better understanding of the employees' exposure to work-related musculoskeletal conditions. And lastly, this research would also benefit the individual with regards to the different effects of an active or a sedentary lifestyle. The target population are adult individuals (age range 18-30) without any medical conditions who are currently enrolled as students at the University of Malta. This population sample was selected as students have varying levels of mobility and can be easily reached through the same intermediary (the Registrar at the University of Malta).

1.4. Justification of the Study

The current research study is intended to analyse the effects of fatigue on gait of the young adult. This endeavour was undertaken in an attempt to identify specific signs of fatigue which could facilitate the clinician in his/her practice to maximise safety within the clinical setting. Clinicians often use patient fatigue, or rather their own perception of what constitutes fatigue, as a limit/block to exercise treatment and/or prescription. The clinician is expected to assess the patient actively during the rehabilitation treatment and cease the exercise once the patient is fatigued. But what signs does the clinician look out for? Does every clinician follow the same signs? Conversely, do patients demonstrate the same effects of fatigue? A deeper analysis into this phenomenon could provide a step-by-step protocol of what constitutes the effects of fatigue upon gait biomechanics.

As previously stated, research on fatigue is abundant, yet there exists a research gap when it comes to analysing the effects of fatigue on the average individual, with most studies preferring to delve into specific niches of individuals' well-being (i.e. obese, athletic, elderly) (Barbieri, et al., 2013). Furthermore, there seems to be another gap when it comes to research of this nature on the Maltese population.

Alterations in gait kinetics, kinematics and spatio-temporal data between pre- and post-fatigue are expected. Variations in the aforementioned data will be manifest depending on the participants' level of activity. Available research have outlined the following:

- Alterations in step width (Helbostad, et al., 2007),
- Alterations in step length (Barbieri, et al., 2013),
- Alterations in time of ground contact (Zhiyong, et al., 2023),
- Increase in shank acceleration across the frontal plane (Zhiyong, et al., 2023),
- Increase in ankle activation during gait (Radzak, et al., 2017),
- Decreased knee flexion (-12%) (Noehren, et al., 2012),
- Increase in ankle plantar flexion (+11%) (Zhou, et al., 2021),
- Postural instability (Slater, et al., 2018),
- Increase in mediolateral movements during gait (Helbostad, et al., 2007),
- Alterations in general symmetry of gait (Radzak, et al., 2017).

The above observations provided the researcher with expected outcomes for the current research. These observations were taken in consideration and reviewed during the Discussion chapter of this dissertation.

1.5. Aims and Objectives

1.5.1. Aim

The aim of this research was to investigate whether the same differences in the gait kinematic, kinetic and spatio-temporal parameters can be observed within the gait of both active and sedentary young adults upon exertion up to the point of maximal fatigue.

1.5.2. Objectives

- To collect gait kinematic, kinetic and spatio-temporal parameters of sedentary/active participants pre- and post-fatigue.
- To analyse the normal and post-fatigue gait data of the participants in order to establish the effects of fatigue on the kinematic, kinetic and spatio-temporal parameters.
- To investigate differences in gait kinematic, kinetic and spatio-temporal parameters between active and sedentary participants so as to establish whether trends vary between the two groups.
- To compare the data collected with pre-existing studies.

1.6. Hypotheses

Alternative Hypothesis H1: There would be significant statistical differences in gait kinematic, kinetic and spatio-temporal parameters obtained from pre- to post-fatigued active and sedentary participants.

Null Hypothesis (H_0): There would be no significant statistical differences in gait kinematic, kinetic and spatio-temporal parameters obtained from pre- to post-fatigued active and sedentary participants.

Alternative Hypothesis H2: There would be significant statistical differences in gait kinematic, kinetic and spatio-temporal parameters when comparing fatigued sedentary to fatigued active individuals.

Null Hypothesis 2 (H_02): There would be no significant statistical differences in gait kinematic, kinetic and spatio-temporal parameters when comparing fatigued sedentary to fatigued active individuals.

1.7. Outcome measures

3D gait analysis, was used within the research as an outcome measure for degrees of movement (kinematics) and force-generation (kinetics) occurring during gait. This analysis was conducted at the Clinical Biomechanics Laboratory at the Faculty of Health Sciences. An 18-camera Vicon Motion Capture System was utilised to measure gait cadence and performance by mapping gait symmetry, and force output utilizing two force plates.

Retroreflective markers were placed upon various key locations on the participants' lower limbs using medical grade tape as dictated by the Plugin-Gait model (Vicon). This system provided a digital map of the participants' gait pattern in space whilst also provided quantifiable data which was used to measure fatigue-induced alterations in gait. The apparatus and the procedure used in the current study is safe and non-invasive to the participants and is standard practice when performing instrumented 3D gait analysis worldwide (including Mater Dei Hospital) (Stief, et al., 2014) (Lee, et al., 2019).

1.8. Significance of research

This research would benefit clinicians like physiotherapists, podiatrists, and occupational therapists within their clinical practice as it would serve them as reference about the effects fatigue can have on the individual and consequently, the safety of the individual. The clinician will be able to differentiate between a person's fatigued walking pattern and his/her normal walking pattern. The data collected and the observations made will aid the clinician to distinguish and notice specific kinematic and kinetic alterations in the examinee's gait pattern which have been outlined as determinants of fatigue, thus promoting examinee safety and individual-specific training intensities. This research would also benefit the individual with regards to the effects of an active or a sedentary lifestyle, facilitating the formulation of appropriate compensatory action to make up for any shortcomings.

1.9. Research Strategy

This research owes its conception mainly to the researcher's experience within various clinical settings, whereby professional opinions varied amongst practitioners. This led to extensive reading into the topic which highlighted the presence of the aforementioned research gap. Once the study was adopted, further reading was done and the best methodology to obtain the above objectives was found to be a quantitative research approach. Burke Johnson, et al., (2007), defined mixed methods as the system that unifies an intellectual (qualitative) with a practical (quantitative) approach. This in turn is able to provide "the most informative, complete, balanced, and useful research results" (Burke Johnson, et al., 2007). The gait analysis and the RPE (Rate of Perceived Exertion) aspect of the research constituted the quantitative measures, and although a handful of questions tackling the participants' level of mobility were performed, these do not constitute a qualitative element in the current research. This quantitative approach provided a more numerical and objective assessment of the participants. A total of 40 participants were recruited for this study. The participants were adult individuals (age range: 18–30) without a well-defined medical condition (or an unexplained fatigue syndrome) who were enrolled as students at the University of Malta. This population sample was selected as students have varying levels of mobility and can be easily reached through the same intermediary (the Registrar at the University of Malta). The participants then attended a one-hour assessment session whereby pre- and post- exercise-induced fatigue gait analysis was conducted, and relevant questions were answered. Following data collection, data interpretation was performed. This allowed the researcher to formulate tangible results, which were corroborated further by established literature. A more detailed rendition of the methodology adopted for this research is discussed within the Methodology chapter (Chapter 3) of the study.

1.10. Signposting (Layout of the dissertation)

This study is made up of a total of five chapters which are divided as follows:

2. Literature Review Chapter: which expands on the introduction already given by delving into the effects of fatigue upon gait and all the other subsequent and relative topics.
3. Methodology Chapter: provides a rendition of the methodological framework adopted for this study.
4. Findings and Interpretation Chapter: elaborates upon the findings and their analysis. As the name implies, an interpretation in the shape of a discussion is provided which analyses and compares the data from this study with the studies in the Literature Review Chapter.
5. Conclusion Chapter: the main findings and observations are stated and the implications of this researched are summarized and presented. This section will also include the current study's strengths and limitations, as well as the study's plans for the future.

1.11. Keywords

Fatigue, exercise tolerance, cadence, gait, RPE, Vicon Motion Capture

Chapter 2: Literature Review

2.1. Overview

Clinical biomechanics is an interdisciplinary field that combines the principles of physics (mechanics), anatomy, and physiology to study human movement and its relationship to health and disease. Biomechanics is an essential component of clinical practice, as it helps clinicians to understand the underlying biomechanical mechanisms of various diseases and injuries and aids them to develop effective treatment strategies.

The literature review aims to provide a comprehensive and critical analysis of the existing research into the effects of fatigue on lower limb biomechanics. This area consists of a thorough search and analysis of published studies, summarization of their findings, and the identification of any gaps or inconsistencies (refer to Section 2.2 below). The ultimate goal of the literature review is to provide a clear understanding of the current state of knowledge on fatigue and what other similar studies concluded upon their examination of this phenomenon.

This literature review covers a wide range of topics, including muscle physiology, gait, gait analysis, gait biomechanics of various types of individuals, fatigue and the measurement of fatigue. The literature in this review consists of validated quantitative and qualitative research studies, as well as reviews and meta-analyses. A deeper observation on the keywords used for this study will be discussed in Section 2.2 below.

The literature review in clinical biomechanics is an important tool for advancing the understanding of the biomechanical mechanisms underlying human movement, and for informing the development of effective clinical interventions for fatigue.

2.2. Search Strategy

The first literature and searches for this study were conducted in November 2021. This draft included the initial literature review which was presented with the proposal. Eventually, the literature was reviewed and given further validity in December 2022 with the introduction of new references and studies. Research databases and portals included: Google Scholar, Pubmed, ScienceDirect and Hydi. Keywords that were fed into these databases included: “fatigue”, “exercise tolerance”, “cadence”, “gait”, “RPE”, “Vicon Motion Capture”, “biomechanics”, “kinetics” and “kinematics”. PICO was utilised extensively in the initial phases of the current research as it guided the researcher to establish a focus for this dissertation. PICO is a commonly used acronym in evidence-based medicine that stands for:

- P: Population or interesting problem
- I: Intervention under consideration
- C: Exposure comparison
- O: Outcomes of interest

The PICO framework is utilised to formulate a clear and focused clinical research question and to direct the search for relevant literature. This system is generally used for quantitative research such as the current study (Bettany-Saltikov, 2010).

The PICO framework was described as having seven integral steps. By following these seven steps, the current research effectively analysed the available literature on biomechanical variations in gait in view of fatigue. The seven steps were as follows:

- Step 1: Formulation of the PICO question

The study began with the formulation of a clear and specific research question within the PICO framework. The question aimed to investigate the impact of maximal fatigue (Intervention) on biomechanical gait parameters in young adults (Population), comparing active and sedentary individuals (Comparison), and analysing changes in kinematic, kinetic, and spatio-temporal gait parameters (Outcome). This research question set the foundation for the entire study.

- Step 2: Identification of Keywords for each Pico Element

To conduct a comprehensive literature search, the study identified relevant keywords for each PICO element.

    - P: Population under investigation (e.g. “young adults”, “active individuals”, “sedentary individuals”, and “level of activity of students”)
    - I: Phenomena of exertion (e.g. “maximal fatigue”, “fatiguing task”, and “exhaustive training”)
    - C: Level of Activity of population (“Active vs Sedentary”)

  - O: Biomechanical Gait phenomena (e.g. "ankle dorsi/plantarflexion," "cadence," "step times," and "stride times")

These keywords were essential for constructing effective search queries.

- Step 3: Plan of Search Strategy

A systematic research strategy approach was utilised to gather relevant literature. The research focused on utilizing general databases such as the UM Hydi and the Google Scholar database systems. Further specified databases, journals, and resources related to Clinical Biomechanics and Gait assessment (e.g. Clinical Biomechanics Journal, and Journal of Applied Biomechanics) were used for the research, ensuring a comprehensive and targeted approach.

- Step 4: Execution of the Search

The various keywords related to Population, Intervention, Comparison, and Outcome were applied to the different aforementioned databases. This yielded a variety of potentially relevant researches and studies.

- Step 5: Refinement of Results

After obtaining search results from Step 4, the studies collected were further screened for relevance by combining two or more keywords from the PICO elements. This process was repeated until studies which were unrelated to the research question were excluded.

- Step 6: Review of the Literature

The amassed literature and studies were reviewed for relevant information. The most significant factors which were taken into consideration were the studies' methodologies, results, and conclusions. These were then evaluated, and used to enhance the literature review by establishing "pre-existing knowledge" and identifying "research gaps".

- Step 7: Determination of the Level of Evidence

As can be noted in the following sections of the literature review (of the current study), the level of evidence and reliability of the studies collected were determined. The process involved an assessment of: the study design, sample size, statistical methods, and the findings of the research. This permitted the current research to provide a detailed literature of the pre-existing studies and it also gave a clear objective for the current research.

The following sections are the valid literature that was gathered through the PICO framework in relevance to gait, clinical biomechanics, fatigue and the effects of fatigue on the various population samples.

2.3. Gait

The aforementioned physiological processes (Sections 1.3., 1.4., and 1.5.) are the main building blocks to understand the physiology of gait. Despite complex neural control, the gait is characterised by smooth and repeatable movements in human joints, which can be recorded by cinematographic methods (Pietraszewski, et al., 2012). Bony alignment, joint range of motion, neuromuscular activity, and the rules that govern bodies in motion, all contribute to the complex activity of gait. A complete gait cycle occurs when all the actions which take place in one instance of gait until the same instance is repeated on the same side, e.g. from heel strike to heel strike (Chambers & Sutherland, 2002).

The different stages of the various muscle contractions/periodic movements within space allowing gait to occur, can be divided into two main phases of gait: The Stance phase and The Swing phase. These two phases are determined by the position of the foot in relation to the ground. The stance phase constitutes all the movements which occur in the lower-limb whilst the foot is in contact with the ground, whilst swing phase incorporates all the movements of the lower limb whilst the foot is being propelled forwards in the air (Perry & Burnfield, 2010). The different positions assumed by the lower-limb during both the stance and swing phases, can be divided into six different instances:

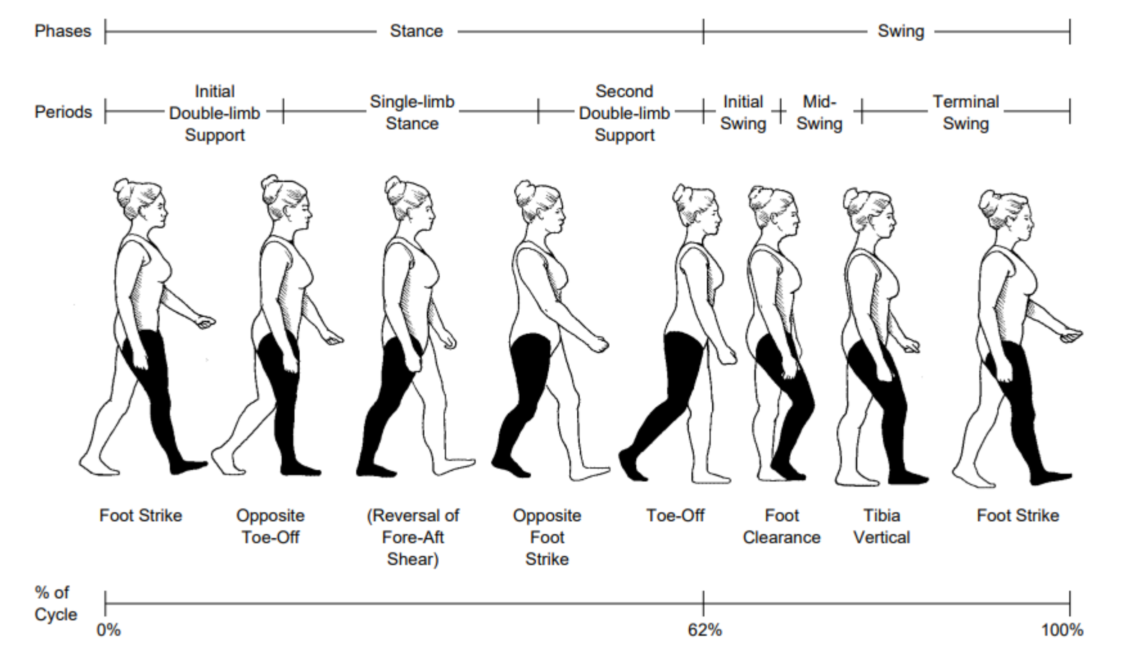


Figure 2.1: Human gait cycle showing stance and swing phase (adapted from Loh & Zulkifli, (2018))

1. **Heel Strike**: as the name implies, this phase initiates when the heel makes contact with the ground. It is at this stage that weight is shifted from the contralateral leg onto the one in heel-strike. It is for this reason that this phase is coined as the 'initial contact'.

2. **Foot Flat**: After heel strike, weight is shifted anteriorly along the foot as it comes into contact with the ground.
3. **Mid-Stance**: At this stage the body weight has shifted entirely on the leg, whilst the other leg has begun its ascent into a swing.
4. **Heel-Off**: This fourth phase begins when the weight has shifted so much anteriorly that it is now on what are known as the balls-of the feet. During this phenomenon, the heel starts lifting off the floor as the contralateral limb has initiated heel-strike.
5. **Toe-Off**: Weight has shifted onto the contralateral leg (mid-stance) whilst this current leg starts its ascent into an eventual swing by having the toe leaving the floor.
6. **Swing**: After toe-off, the leg swings forward in what is known as a stride and will eventually descend back towards the ground forming another heel-strike. The swing phase is subdivided into two further phases: acceleration phase and deceleration phase. The acceleration period starts from toe-off to mid-swing. The deceleration phase starts from mid-swing to heel-strike (Perry & Burnfield, 2010).

Phases 1-5 constitute the stance phase (which consists of 60% of the full gait cycle), whilst phase 6 is considered the swing phase (which constitutes 40% of the gait cycle) (Perry & Burnfield, 2010)(Karvekar, 2019).

At each stage of the gait cycle, different physical forces are being exerted on the individual. To be able to understand and analyse a person's gait, one needs to go through the kinetics and the kinematics of gait.

2.4. Different types of Gait

The various gait patterns are a subject of hot debate within the research community. Some studies outline significant variabilities in the biomechanical data of asymptomatic gait (Mezghani, et al., 2013); whilst others like Mezghani, et al., (2013), and Horst, et al., (2016), postulate that variations in the walking patterns of asymptomatic individuals usually fit into the standard deviation of values of the mean curve. Horst, et al., (2016), state that an individual is able to experience discernible daily variations in gait throughout his/her life and that the differences in gait patterns generally persist up to two weeks at a time. The study goes on to explain that variability is an "inherent feature" of human motor control and the biomechanical output of an individual. The same study goes on to state that various intrinsic and external factors affect gait (Horst, et al., 2016); these are discussed in the literature review chapter of the current study. Notwithstanding such factors, the study by Pietraszewski, et al., (2012), outlines how variability within the same session is reduced since an individual will seek to maintain a certain biomechanical uniformity throughout the session. The author thus described the gait variables as "quite repeatable and quite uniform" (Pietraszewski, et al., 2012).

2.5. Gait Analysis in the Motion Analysis Laboratory

Observational gait analysis (defined within Section 2.6.) is limited by human error and limitations. Electromyography machines (EMGs), force plates, and cameras can provide a clearer biomechanical picture of the phenomena occurring during gait (Chambers & Sutherland, 2002). Within an examination setting, various parameters can be reported from a gait pattern. These include:

- Temporal Parameters: velocity, stride length, step length and cadence (number of steps per minute);
- Kinetics (which include various forces that occur in upper limbs as well as lower limbs during gait; and foot pressure);
- Kinematics (which includes the six determinants of gait: pelvic rotation, pelvic list (pelvic obliquity), knee flexion instance, foot and ankle motion, lateral displacement of the pelvis, and axial rotations of the lower extremities);
- Energetics.

2.5.1. Gait Analysis

Gait analysis is the study of human locomotion, which includes the analysis of various physical parameters such as body posture, alignment, joint angles, and walking or running movement patterns. Gait analysis can be utilised to diagnose and evaluate musculoskeletal and neurological conditions that influence gait, as well as to design and monitor rehabilitation and treatment. There are various gait analysis techniques, such as observational gait analysis, video gait analysis, and instrumented gait analysis (Perry & Burnfield, 2010):

Observational Gait analysis is a method for evaluating a person's walking or running style. This technique involves visually observing the individual's gait pattern in order to detect any deviations or abnormalities in the individual's movement, posture, and body alignment while walking or sprinting. Observational gait analysis can be used to diagnose and evaluate conditions that affect locomotion, including musculoskeletal injuries, neurological disorders, and developmental disabilities. It can also be used to track rehabilitation or treatment progress for these conditions. This system is subjective as it relies on the examiner's knowledge and attentiveness (Perry & Burnfield, 2010).

Video Gait analysis is a form of gait analysis that involves recording and analysing a person's walking or running gait using video cameras to identify any abnormalities or deviations in the individual's movement patterns. Kinematic parameters may be evaluated more effectively during a video gait analysis. Video gait analysis is frequently used in sports medicine and physiotherapy to evaluate and enhance athletic performance, as well as to diagnose and treat gait-related injuries and conditions. It can also be used to analyse human movement and gait patterns in biomechanics research (Willson & Davis, 2008).

Instrumented Gait analysis can be defined as the instrumented measurement of the movement patterns that make up walking (kinematic and kinetic measurements) and the associated interpretation of the data. Various other tools can be used in association with gait analysis, such as electromyography (EMG), oxygen consumption and foot pressures (Baker, 2006). For the current research, Vicon Motion Capture along with its Vicon Nexus programme were used as gait analysis tools.

2.5.2. History

Modern clinical gait analysis knows its origins to around the early 1980s with the opening of a laboratory developed by the United Technologies Corporation at Newington, Connecticut. The protocol adopted to assess gait included the placement of retro-reflective markers on the skin according to various anatomical landmarks. These markers were illuminated stroboscopically and detected by modified video cameras. The logic in place revolved around the concept that if two or more calibrated and aligned cameras were able to detect a marker, then the location along a 3-D space of that marker could be deduced (Baker, 2006).

This same logic is still incorporated today with laboratories now using 8, 10 or more cameras functioning at over 100 Hz and capable of detecting reliably the presence of tens of markers of diameters between 9 and 25 mm. The calibration of the cameras (i.e. the position, orientation and optical and electronic characteristics) can generally be achieved in less than a minute and marker positions from captures can be reconstructed and labelled automatically. Furthermore, the cameras have improved so much that they are able to capture 1 mm differences in marker sizes (Baker, 2006).

2.5.3. Gait Kinetics

Gait kinetics delves into the forces and moments that result in the movement direction of an individual's gait, but most especially it focuses on the varying GRFs on the foot. This can be observed via force plate system which are stationary devices that record this phenomenon, when walked upon (Leusmann, et al., 2011). During an assessment, only one foot should fall on one force plate, allowing a weight distribution mapping system of a step across time from heel-strike to toe-off. Therefore, the integration of two consecutive force plates would demonstrate the stance phase of both lower limbs during gait.

2.5.4. Gait Kinematics

Gait Kinematics on the other hand delves into the angles and mapping of the various joints and segments of the lower limb during gait. This can be observed via the Vicon Motion Capture system whereby an individual has numerous small and lightweight reflective markers placed on his person providing mapping data of his movements during gait via 18 cameras tuned to a particular walk-way (Karvekar, 2019).

2.5.5. Energetics

As the name implies, energetics delve into the measurement of energy expenditure. Measurements for energy expenditure include:

- Blood Oxygen concentration during ambulation. Which can be collected via pulse oximetry and mathematical conversion models;
- Pulse rate during ambulation. Also collected via pulse oximetry and mathematical conversion models;
- Mechanical Work done during ambulation. Can be worked out mathematically from the force plate data collected (Chambers & Sutherland, 2002).

2.6. Physiology of Fatigue

When it comes to physiology that takes place during "performance fatigue", we need to once again delve into the aforementioned sarcomere action which predisposes muscular contraction. As has already been stated, fatigue is the inability for an individual to perform a task due to exertion. At the sarcomere level, fatigue is defined as the inability of a muscle to maintain or perform a contraction, thus stimulation of said muscle is inhibited. Usually, a muscle would be unable to perform a contraction because of an increase in the activation threshold of the muscle being stimulated. According to Burnley and Jones, (2016), this phenomenon is in turn influenced by the intensity of the exercise being performed (Burnley & Jones, 2016). Examples of causes for the reduction in muscular synaptic activation include:

- A reduction in the will for the exercise (usually in the moderate exercise intensity domain; e.g. extremely prolonged exercise);

- Depletion of muscular fuel reserves (during heavy intensity exercise);
- Accumulation of fatigue-inducing metabolites (during severe-intensity exercise).

The aforementioned principles are generally observed following exercise. These phenomena do not necessarily occur with “domestic fatigue”. A more general approach of viewing and perceiving fatigue is warranted to observe domestic fatigue (McLean, et al., 2007) (Borotikar, et al., 2008) (Wang, et al., 2012) (Schmitt, et al., 2013).

A general fatigue strategy is one which observes both the local and central fatigue generated by exertion, regardless of whether they are simulated by daily or sports activities. A general fatigue strategy shifts the focus from specific muscle-generated fatigue to alterations in gross movement following fatigue (McLean, et al., 2007). Studies have defined this approach as the assessment of maximal fatigue levels based on volitional exhaustion. In other words, fatigue is measured by the inability of a participant to perform a specific component of the fatiguing task/s. Assuming participants actually achieve fatigue by reaching a “realistic exhaustive end point”, and that the exercise being performed truly affects the muscle groups being observed, then this approach reduces the inter-subjects variations in fatigue levels (Wang, et al., 2012).

Studies have defined this approach as the assessment of maximal fatigue levels based on volitional exhaustion (Bazuelo-Ruiz, et al., 2018). Therefore, fatigue is measured by the inability of a participant to perform a specific component of the fatiguing task/s.

2.7. Fatigue and biomechanics of gait

2.7.1. General effects

As stipulated in the physiology of fatigue section, numerous factors influence muscular contraction during fatigue-inducing exercise. Lactate build-up and alterations in motor-firing will result in a change in the muscular tone of the person performing the exercise. Radzak, et al., (2017), state that numerous kinematic and kinetic measures were altered in their study by an event they dubbed as “fatigue-induced stiffness”. This stiffness altered a number of components:

dorsiflexion, plantarflexion, hip ab/adduction, knee internal rotation excursion, maximum velocity, mean velocity and maximum moment, knee flexion moment during loading response, and all GRF variables. This is supported by other authors who associate similar kinematic changes with fatigue-induced stiffness, including Noehren, et al., (2007); and Noehren, et al., (2012). If contractions are still forcefully generated by the fatiguing muscle, the “stiff” exercising muscles will not obtain substantial amounts of oxygen, thus fatigue eventually leads to contraction failure (Stringer, et al., 1994) (Halson, 2014) (Karvekar, 2019). Whether such contraction failure is achieved or not, the force and power generated by the exercising muscle will be reduced, thus reducing said muscle’s efficiency. The reduction of power in lower limb muscles will influence proprioception and speed (Stringer, et al., 1994) (Wang, et al., 2012) (Barbieri, et al., 2013) (Radzak, et al., 2017). This was also observed by Yoshino, et al., (2004) as already indicated in the Introduction. Further observations included: slower gait speeds, with higher stride-to-stride variability and increased local dynamic stability (Yoshino, et al., 2004). This was in view of the fact that the participants subconsciously started widening their base-of-support during gait as they got more exhausted and slower. The article by Morin, et al., (2011), further observed an increase in the foot’s “ground-contact time” of their participants (Morin, et al., 2011). Similarly, in the study by Voloshin, et al., (1998), active participants had compensatory mechanisms in place which allowed for kinetic and kinematic changes to occur during gait/running. These mechanisms prevent a significant increase of dynamic loading towards the end of a 30 min long run and thus prevent injuries (Voloshin, et al., 1998). A similar observation was registered by Derrick, et al., (2002), who state that although the movement pattern is altered with muscular fatigue, the goal of the task is preserved (Hills, et al., 2001) (Helbostad, et al., 2007) (Ko, et al., 2010) (Barbieri, et al., 2013) (Bazuelo-Ruiz, et al., 2018) (Slater, et al., 2018).

Other studies also delved into the effects of fatigue on spatio-temporal parameters. Such studies include the ones by Gerlach, et al., (2005), Hunter & Smith,(2007), and Morin, et al., (2011). These studies demonstrated that, upon fatigue, the frequency of steps per minute increased.

Fatigue is a condition of physical and/or mental exhaustion caused by prolonged physical activity; prolonged mental activity; and inadequate rest. According to global statistics, roughly 20% of men and 30% of women in the general population report frequent fatigue (Jason, et al., 2009). The study by Cella et al., (2002), outlines how 55% of healthy individuals identified a physical sensation of fatigue/tiredness, 21% identified an affective sensation of fatigue, and 24% identified cognitive fatigue. This was further described as "Healthy Fatigue" (Cella, et al., 2002).

For athletes, fatigue can result in diminished performance, a higher risk of injury, and lengthier recovery periods. Muscle fatigue caused by prolonged and strenuous physical activity can impair coordination, reduce reaction time, and increase the risk of falls and accidents. This has been referred to as biomechanical fatigue (Komaroff & Cho, 2019) (Charest & Grandner, 2022).

Similarly, cardiovascular fatigue is associated with the cardiovascular system and occurs when the heart and blood vessels become fatigued as a result of protracted or intense physical activity. This type of fatigue can reduce an athlete's endurance, increase their pulse rate, and lower their blood pressure, all of which can impair their performance.

In addition, mental fatigue (cognitive fatigue) can impair an athlete's decision-making, concentration, and motivation, all of which have a negative effect on performance. Charest and Grandner, in their 2022 study, observed that sleep health is an essential factor for athletic performance. Athletes are highly susceptible to insufficient sleep duration, poor sleep quality, daytime drowsiness and fatigue, suboptimal/irregular sleep schedules, and sleep and circadian disorders.

Within the workplace, fatigue-related ailments and injuries can result in increased healthcare costs and decreased productivity, both of which have a negative effect on the economic output of the individual. Fatigue can lead to decreased productivity, increased absenteeism, and higher accident and injury rates in the workplace (Komaroff & Cho, 2019). This type of fatigue falls under the category of psychological fatigue (Karvekar, 2019). Psychological fatigue is caused by the mental and emotional demands of a task or situation, and it occurs when an athlete or worker is under high levels of stress or has engaged in mentally demanding tasks for extended periods of time. Fatigued workers are more likely to commit errors, have impaired judgment, and have delayed reaction times, which increase the risk of accidents and errors. Work-related musculoskeletal disorders (WMSDs) also increase, as WSMDs can also be classified under possible accidents that could occur within the work-place. WMSDs are repetitive strain injuries, which are known as the most common work-related health problems and causes of fatigue (Hockey, 2013). In the study by Hosseini, et al., (2021), it was outlined that fatigue accounted for 29% of all US workplace injuries.

Chronic fatigue syndrome (CFS) is typically diagnosed in patients with excessive fatigability for which there is no adequate medical explanation. It is characterized by more than six months of chronic fatigue that is not alleviated by rest. Symptoms include post exertion malaise (PEM), unrefreshing sleep, cognitive impairment, autonomic dysfunction, and/or muscle or joint discomfort. It is known that CFS is associated with low health-related quality of life. In fact, 25 to 29% of CFS patients are reported to be housebound or bedridden, more than half of the patients are unemployed, and only 19% are full-time employees (Komaroff & Cho, 2019). According to the study by Lewis and Wessely, (1992), fatigue complaints are extremely prevalent in developed nations. In the US Health and Nutrition Examination Survey, the prevalence of fatigue was 14.3% in men and 20.4% in women (Lewis & Wessely, 1992). This condition is likely to be as prevalent as rheumatoid arthritis, as it affects approximately 1% of the global population, or 17 to 24 million individuals. However, the absence of an objective diagnostic instrument has made accurate estimation of prevalence difficult (Lim, et al., 2020). Fatigue can impact the physical and mental health, performance, and safety of athletes and employees on a global scale.

2.7.2. Effects of Obesity

Studies by Handrigan, et al., (2017), and LaRoche, et al., (2015), observed that obesity presented the individuals with some physical limitations, including movement difficulties, limitations in activities of daily living and limitations in general mobility activities. Other studies established that obesity in adults is also associated with altered postural control during quiet standing (Hills, et al., 2001) (Wu & Madigan, 2014) (Maktouf, et al., 2020). Obese individuals experience greater absolute loads and perform more work at various weight-bearing joints than individuals of normal weight (LaRoche, et al., 2015). Repetitive activities such as gait cause persistent loading upon these joints and it follows that obese individuals are more predisposed to pathological gait patterns, loss of mobility and subsequent progression of disability (Maktouf, et al., 2020).

2.7.3. Effects of Age

A large proportion of age-associated falls are attributed to a decreased quality of gait due to age-related peripheral issues such as decreased postural control and muscle strength) (Gimmon, et al., 2015) and central impairments, such as atrophy of the motor cortical regions and delayed muscular commands (Maslivec, et al., 2018). Helbostad, et al., (2007), did in fact report neuro-musculoskeletal system alterations in elderly gait. An increase in muscle activation in the lower limbs occurs, mainly in the tibialis anterior (TA) and soleus (SOL) during the single support phase and in the gait movement during the first support phase (Helbostad, et al., 2007). The shift of muscle group fatigue is not accidental. Whereas younger individuals achieve muscular fatigue within proximal muscle groups, an older population sample achieves fatigue in more distal muscle groups. This can be associated with the type and the intensity of the exercise the older population performs. The research by Barbieri, et al., (2013), which had a mixed population sample of young and old participants, outlines how the older participants engaged more with walking or fast-walking, whilst the younger population engaged in more dynamic exercises. In their findings, the authors noted that the younger population demonstrated reductions in gait speed and stride length. The same was not noted within the older population. The authors explained this phenomenon by implying that the younger sample adopted a “conservative strategy” to deal with fatigue which was absent in the older population. This was explained as an indicator and a safety measure to reduce risk of fall injuries (Barbieri, et al., 2013). Participants within the articles of Helbostad, et al., (2007), and Barbieri, et al., (2013), seemed to control the movements of their lower limbs along the sagittal plane.

The observations registered for older individuals are similar to the adaptations of obese individuals, whereby changes in cadence were associated with an attempt to keep a constant or optimal output, at the expense of “normative” cadence.

2.7.4. Athletic individuals

As discussed earlier, the study by Yoshino et al. (2004), had two main groups. One group (Group B) had nearly negligible variations in their data collection. These individuals had more active lifestyles, and participated in sports with physical intensities of varying degrees. The second group (Group A), on the other hand, were sedentary and did have significant changes in their gait. The authors go on to say that the difference in participants' level of stamina might have been the main factor causing the differences in gait and physiological rhythm during the long-term walking task (Yoshino, et al., 2004).

In summary, the differences between Group A and Group B were:

- Group B did not slow down in their gait rhythm,
- Group B showed more stable gait rhythm than Group A,
- Group B did not show significant muscular fatigue (Yoshino, et al., 2004).

In the study by Voloshin, et al., (1998), it was observed that active participants have compensatory mechanisms in place which can counter-act the effects of fatigue. These compensatory mechanisms remain in place if said athletes do not reach an exhaustive-fatigue state. The authors explain, that before athletes reach this state they demonstrate alterations in kinetic and kinematic measures during gait/running which can be associated to the aforementioned compensatory mechanisms. Again, these compensatory mechanisms are systems which athletes have developed within their training and which serve to prevent a significant increase of dynamic loading and prevent injuries (Voloshin, et al., 1998) (Hills, et al., 2001) (Derrick, et al., 2002) (Bazuelo-Ruiz, et al., 2018) (Slater, et al., 2018).

Apart from the compensatory mechanisms, some authors have linked the changes in kinematic and kinetic data to fatigue and decision-making alterations. Borotikar, et al., (2008) state that these two phenomena co-exist within a sport environment as athletes would need to adapt to various situations which their respective sport could present. They also associate this phenomenon as a risk factor of ACL injury (Borotikar, et al., 2008). Furthermore, this phenomenon might be aggravated since fatigue and reactions compromise both central and peripheral processing mechanisms thus resulting in "poor" movement strategies (Wang, et al., 2012).

Meeusen, et al., (2013), describe that in athletes, fatigue processes can be classified as voluntary and controlled fatigue. The balance between these two processes is necessary for performance progression. Performance progression along with appropriate recovery periods has been termed functional over-reaching (FOR). On the other hand, involuntary and uncontrolled fatigue that requires a prolonged period of recovery and rest known as non-functional over-reaching (NFOR) or overtraining (OT) (Meeusen, et al., 2013). Interestingly the latter may cause de-conditioning on a fitness level, be it muscular or cardiovascular. Several researches that delve into the relationship between HRV and fatigue assess participants who are either in a state of FOR or NFOR/OT. An example of one such study is the research conducted by Hedelin, et al., (2000), who noted that nine FOR canoeists demonstrated no alteration in HRV values after increasing their training load by 50% over a 6-day training camp. Schmitt, et al., (2013), discuss that the fatigue-HRV results gathered from numerous studies have high inter-individual variations. Plews et al., (2013), expand on this by outlining how HRV values can be affected by numerous external factors which include: age, gender, heritability, noise, temperature, light, and prior exercise. Schmitt, et al., (2013), denoted that the sedentary and normal population within research are the most susceptible to such influences (Schmitt, et al., 2013). Again, this was also observed by Yoshino, et al., (2004), who noticed that the HR readings for Group B were more stable throughout the long-distance walking than Group A.

One element of fatigue that can alter in athletes is variability of movement. It is normal for the movement of one lower limb to be unequal to the movement of the contralateral side. In the study by Radzak et al. (2017), the authors found that there were differences between the cadence of a well-rested athlete and that of a fatigued one. Interestingly enough, fatigue did not always aggravate the asymmetry in the athlete’s cadence; some athletes demonstrated different asymmetries pre- and post- the fatiguing protocol (Radzak, et al., 2017).

Ultimately, the research by Hanley & Tucker, (2018), concluded that there were negligible effects of fatigue on their well-trained distance runners (Hanley & Tucker, 2018) (Forestier & Nougier, 1998).

2.7.5. Work-related Musculoskeletal Disorders (WMSD)

As established in the previous sections, fatigue alters numerous biomechanical aspects of gait. This can result from repetitive movements such as sit-to-stands or even gait. According to Karvekar (2019), the present day individual is more prone to work-related musculoskeletal ailments than previous generations have been. The most predominant of conditions are back and neck pains. Fatigue within the work environment can be quite detrimental to the individual as it may lead to what are known as Work-related Musculoskeletal Disorders (WMSD). If ignored, fatigue may lead up to Myalgic Encephalomyelitis (ME) and Chronic Fatigue Syndrome (CFS). Individuals with the aforementioned conditions end up exhausted to a point where they would be physically unable to perform basic Activities of Daily Living (ADLs). Consequently, the monitoring of fatigue as a preventative measure cannot be overstated (Karvekar, 2019).

WMSDs can negatively impact personal health and can also create an economic burden for the employer and employee. As a general definition, WMSDs are disorders of the muscle, skeleton, and related tissues that develop over time with repetitive motion or strain. WMSDs affect motor control ability, postural stability, and gait alterations, thereby decreasing worker performance, lowering productivity, decreasing quality and increasing incidences of injuries at work (Karvekar, 2019).

2.7.6. Sedentary vs Active lifestyle

Physical activity has been outlined to incorporate any movement that involves more energy expenditure than when a person is at rest (Torbeyns, et al., 2014). Maintaining an active lifestyle has numerous benefits which have been outlined to include: an increases an individual's quality of life, and the promotion of brain plasticity. A sedentary activity, on the other hand, has been defined as any waking activity that uses the same energy-expenditure as a sitting or lying down. Within the work-place and domiciliary environments, the energy-expenditure require to conduct daily activities have reduced (Torbeyns, et al., 2014). As previously discussed, there are notable disparities between the impact of fatigue on a person's gait depending on whether they are active or sedentary. Yoshino, et al. (2004) investigated these phenomena and found that, in contrast to their sedentary counterparts, the active participants did not exhibit any substantial physiological or muscular weariness following a 3-hour exercise session (Yoshino, et al., 2004). According to Puetz, et al., (2008), a substantial number of adults around the world have chronic fatigue as a result of physical inactivity. The authors go on to explain that, with appropriate training, the rate of perceived exertion scores decreased for higher intensities and a better quality of life was observed within their participants (Puetz, et al., 2008).

Various studies outlined how the fatigued gait pattern changes in order to reduce dynamic loading and prevent lower limb injuries (Padua, et al., 2006) (Zhou, et al., 2021) (Zhang, et al., 2022). This loading mechanism was described as a compensatory mechanism adopted by active participants who regularly adopted these systems to augment sports-related performance. The same article goes on to describe that this loading-modification-mechanism enables changes in distal movements which allow for subtle proximal alterations of movement. As described earlier, the lack of this modification and the lack of regular activity predisposes more significant fatigue-induced changes in sedentary individuals (Zhou, et al., 2021).

Unfortunately, even though there are literature which outline a particular biomechanical phenomenon, an abundance of polarising literature is available. The research by Edwards, et al., (2012), Bazuelo-Ruiz, et al., (2018), and Slater et al., (2018), outlines how the knee and ankle joint kinematic parameters of gait within heel strike are important factors for joint stability and demonstrate kinematic and kinetic change when submitted to fatigue. However, Nicol, et al., (1991), and Dutto, et al., (1997), observed otherwise within their research. It is worth noting that many of the aforementioned authors did not delve into whether the participants were active or sedentary. As stated earlier, the research by Padua, et al., (2006), distinguished active participants from sedentary participants, and noticed that it was highly probable that the active participants were more aware of the correct positioning of the foot during gait than their sedentary counterparts. Similar observations were reported in the studies by Schmitt, et al., (2013), Barbieri, et al., (2013), Zhou, et al., (2021), and Zhang, et al., (2022).

2.8. Conclusion

As can be observed from the literature collected, numerous studies have delved into the effects of fatigue on the human body. Much of the available literature focused on the aforementioned niches (younger, older, obese, athletic individuals). However, as Puetz, et al., (2008), and Torbeyns, et al., (2014) found few studies that addressed the effects of fatigue on individuals without a well-defined medical condition or an unexplained fatigue syndrome. This renders a limited view on the effects of fatigue as the average adult may not belong to either of these groups. When applied to the current research, one would expect that the literature outlining younger and athletic individuals pertains to active participants whilst the obese and older individuals conform to the understanding of sedentary /less active participants. This study aims to gain a wider perspective of the effect of fatigue by having a population sample of varying ages and lifestyles, and to provide data which applies to the average general population.

Chapter 3: Methodology

3.1. Introduction

The methodology chapter is a critical section that provides a detailed description of the methods and procedures used in the study. This section outlines how the current research was conducted and how the data was collected, analysed, and interpreted.

The data collection process is also described in detail, including the instruments or equipment used to collect data, the procedures followed to collect data, and the quality control measures used to ensure accuracy and consistency.

In addition to describing the data collection process, subsequent sections include a clear and detailed explanation of the data analysis methods used. This consists of a description of the statistical tests used to analyse the data, and any assumptions made during the analysis.

Furthermore, this chapter describes any ethical considerations related to the study, including the informed consent process, and the protection of human subjects.

This chapter is divided into:

- Ethical approval
- Ethical Considerations
- Research Design
- Methodological Framework
- Search Strategy
- List of Participants
- Research Tools and Data Collection
- Data collection session
- Data Capture and Processing
- Processing Routine
- Data Analysis
- Validity and Reliability of data

3.2. Ethical approval

An ethics proposal form was drafted and submitted to the Faculty of Research Ethics Committee (FREC) and the University of Malta Research Ethics Committee (UREC) for approval before commencement of the research. The proposal included various sections delving into the ethical considerations and principles which were adopted within the current research. The layout of the principles selected conformed to the Declaration of Helsinki, which is a set of ethical principles that guide medical research involving human subjects. Principles which were adopted in accordance to the Declaration of Helsinki, (2013), included:

- Signed informed consent achieved from the research participants,
- Participants' privacy and confidentiality was maintained,
- This research being a scientifically valid and socially relevant study,
- Numerous considerations were implemented with the sole purpose of minimizing harm and maximizing the benefits for research participants,
- Consideration and respect for various cultural and religious beliefs was promoted to ensure that research was conducted in a manner that is consistent with ethical principles.

Ethical approval for this study was achieved through University of Malta's Research Ethics Committee (UREC) Application No. FHS-2022-00019 (Appendix Form 6) and through Faculty Research Ethics Committee (FREC).

Participants were provided with a thorough verbal and written explanation (available in English and Maltese, based on their preference) of the purpose of this study. Upon acceptance, written consent was obtained, in which it was made clear that all information would be kept confidential and that personal information would be destroyed upon completion of the study. As required by the World Medical Association Declaration of Helsinki (WMA, 2013), each participant was assigned a coded number that was only known to the researcher. It was made clear that participants had the right to withdraw at any time during the research procedure, in which case their information would be discarded. During the study, it was ensured that participants were not misled in any way and were not at risk of injury.

3.3. Ethical Considerations

To participate in the current study, an information letter with an attached consent form was given to the participants, together with the introductory letter. Special attention was given to the writing of the information letter, with a detailed description of what the research entailed; how anonymity and confidentiality was to be kept; and the flexible nature of the participation within this research (Steffen, 2016). Questions posed by the participants were addressed prior and during the data collection session. This was done to promote ethical professionality throughout the participant's experience as a subject within the current study.

The participants eligible for this study were University of Malta students who are able to mobilise independently and have good balance. This reduced the likelihood of falls and injuries from the participants. Then again, the design of the study allowed the participants freedom to pace themselves as they deemed fit during the experimental aspect of the data collection session without receiving any bias or extra coaxing/motivation to induce better performance. Participants were instructed to stop the session whenever HR and SPO_2 parameters reached high values. Furthermore, the session was stopped whenever the participant said that s/he was fatigued with a score of 20 on the RPE scale. Along the same lines, the participants were instructed to stop or slow down to ensure safety whenever the researcher noticed that the participants were fatigued and did not stop the session voluntarily.

Permission and consent for participant recruitment rights and permission for gait-lab use were acquired from the University of Malta prior to the FREC application.

Treadmill walking/jogging: The treadmill did not present any risk of injury for the participants as it is a safe apparatus with easy controls to manage. This by itself makes this assessment a very low risk intervention. As stated before, the participants chosen for this study had a high degree of mobility and balance-control, therefore the likelihood of injuries and accidents during the data collection session were deemed to be minimal.

In the likelihood of an emergency, the following measures were in place:

- qualified health-care professional present at the data collection session (the researcher, a registered, First Aid certified, SAHP-Physiotherapist with five years' experience of working within the hospital setting),

- venue for data collection was close to the Mater Dei Hospital premises,
- sessions were conducted within a safe environment,
- assessment area was spacious and allowed the researcher to aid participants should the need arise,
- experimental session was conducted on safe apparata,
- a hoist was in place to aid the participant should the need arise,
- participants were instructed to pace themselves comfortably,
- participants were given individual attention.

As the current research consisted of physical examinations; movement capture; and anthropometric data collection, various ethical considerations needed to be included within the methodological framework, to maintain the participants' dignity and data protection. The likelihood that participants' identity might have been revealed was negligible. The nature of the data collected included:

- Anthropometric data: age, weight, height, waist girth, hip girth, ASIS distance, leg length, knee width, and ankle width;
- Lifestyle Level of Activity;
- Mapping Data (Vicon Motion Capture).

The aforementioned data was inputted in the data sheet (Appendix Form 3) and each participant was given a code. Thus the participants' identities remained anonymous.

All the data collected was immediately processed onto a results workbook on Excel and the hard-copy version was destroyed immediately during the data collection session. The data in the Excel workbook was saved onto a password-protected hard-disk in a password-protected folder and accessed on the researcher's personal, password-protected laptop running on Windows 10 using Folder Lock 7.8.4 as an encryption software. The personal data was not stored in any other computer devices and was not uploaded to any cloud servers. A backup was made on a password-protected external hard drive using the same encryption system, which was kept safely under lock and key, to which only the researcher had access (Bryman, 2012) (Bryman, 2016). All non-personal information remained private until the dissertation was published, and was only shared with relevant UM staff for guidance purposes whenever necessary. Moreover, once the study was finalized, all hardcopy documentation and softcopy files were erased. This was done to maintain the confidentiality of the participants in accordance with the General Data Protection Act and Malta Data Protection Act (2018).

Finally, no participants were harmed, nor were they given any compensation to participate in this study.

3.4. Research Design

One can classify the main aspects of research design into three main groups:

1. **Quantitative research**: an approach which addresses and manipulates a research topic from a numerical point of view.
2. **Qualitative research**: an approach which is more descriptive in nature. It focuses more on the interpretation of the research's perception of a phenomenon or an experience.
3. **Mixed Methodology research**: is a combination of both of the above styles (Bryman, 2012).

In more than one body of research, qualitative data has been viewed as a more valid and rich approach in comparison to its numerical counterpart. However, qualitative research has also been described as "too subjective" in light of the fact that in most cases qualitative research delves into an individual's personal opinion and/or feelings. This is why qualitative research is usually implemented in a social or psychological context (Dey, 1993).

On the other hand, quantitative researches' approach consists of systematic investigations of social phenomena, with the extrapolation of statistical/numerical data. Measurement is a key term when considering quantitative research. A strong quantitative study expresses said measurements with a thorough analysis of trends and relationships (Watson, 2015). Measurements within a quantitative research are described as "variables". These variables are also classified as either "independent" or "dependent" (Pierce, 2013), with the independent variable able to influence the dependent one (Watson, 2015). Finally, quantitative research has also been further classified into: Survey Research, Correlational Research, Experimental Research and Causal-Comparative Research.

The Mixed Methods approach is an amalgamation of the aforementioned research styles, making it a union of the quantitative and qualitative methods. This approach brings forth a unique phenomenon of delving into qualitative hypotheses *vis-à-vis* a statistical analysis (Watson, 2015).

Since the current study aims to measure the effects of fatigue on gait, the research can be viewed as a quantitative, correlational, experimental study.

Correlational: Correlational quantitative research designs examine the relationship between two or more variables whilst also analysing the strength and trajectory of their relationship. This research design permits the development of hypothesis and observations but it does not prove causality and other events may impact the relationship being observed (Babbie, 2016). This is where the experimental research design elevates the current research.

Experimental: Quantitative experimental research designs permit the evaluation of the effect of one or more factors on a dependent variable. This design permits the manipulation of one of more independent variables whilst maintaining a constant dependent variable to establish cause-and-effect linkages (Babbie, 2016). In experimental research studies, the research design divides participants into a control group that does not receive the experimental treatment, and one or more experimental groups that do receive an experimental treatment. The difference in the final readings between the control and experimental group(s) would demonstrate the effect of the independent variable on the dependent (Aronson, et al., 2018). As outlined previously, experimental designs can prove causality and test hypotheses by illuminating variable linkages in a quantifiable manner.

Thus, a quantitative, correlational, experimental approach was selected by the current researcher, as the current research aims to gather numerical data which will outline the effect of a particular phenomenon (in this case: fatigue). From said numerical data, patterns and trends in the cadence and gait of an individual before and after fatigue were studied. The study further examines the reason why certain individuals fatigued quicker or even differently from others by having the participants answer questions about their occupation and physical level of activity.

3.5. Methodological Framework

When evaluating the current study with the stipulated descriptions of the quantitative research design, one might deduce that this study can also be described as both experimental and correlational.

An experimental study consists of an exercise which is able to investigate the interaction between independent and dependent variables, and deduce a cause-and-effect relationship. As the name suggests, this subsidiary of quantitative research relies on the investigation of the aforementioned variables within an experimental setting. The current study evaluates the effects of fatigue (independent variable) upon the gait cycles of the participants (dependent variable) (Saigo, 2022).

A correlational study can be defined as research which is able to predict a relationship among two or more variables (Saigo, 2022) (Seeram, 2019). Seeram, (2019), explained that this approach can also shed light on interacting variables, and their effect on an external variable (Seeram, 2019). In the current study (as can be seen by the data trends in the Data Analysis section within this same chapter), anthropometric data, experimental numerical data and descriptive data (gathered from the data sheet) have been correlated. This means that more than two sets of data-related values have been compared against each other and further results were extrapolated from this comparison.

The following sections are an in-depth description of the experimental design adopted within this study.

3.6. Philosophical framework

The philosophical framework of scientific research provides the underlying principles that guide the scientific process. Scientific research can be defined as the endeavour of acquiring knowledge through objective observation (analysis) and experimentation (Bryman, 2016).

There are various philosophical ideas and methods behind the research and the analysis of a scientific inquiry, these include:

- **Socially constructed**: This method is used to interpret and understand the population's perception of the matter being addressed. The researcher examines the population’s views and meaning about a phenomenon. This type of paradigm is more relevant to qualitative research with open-ended questions which allow the participants freedom to express their opinions fully without any bias (Gergen, 2015). This paradigm was not adopted within the current study since the research design is quantitative in nature.

- **Advocacy/Participatory**: This type of enquiry delves into a more political viewpoint. Data in research which adopts this paradigm is usually qualitative, but this paradigm permits the development of quantitative research. This approach is typically used when observing the needs and knowledge of marginalized groups within a population. The current dissertation does not focus on the interpretation of politics and political agendas within a population, thus, this approach was not applicable (Wallerstein & Duran, 2010).
- **Pragmatic**: This approach delves in the observation of actions, situations, and consequences rather than pre-existing conditions. In this paradigm, both qualitative and quantitative methods are used to examine a phenomenon (Creswell & Plano Clark, 2018). Pragmatism was not applicable for the current research as the nature of this study is quantitative and not mixed.
- **Postpositive (empirical science)**: This paradigm incorporates a cause-to-effect ideology and is implemented in quantitative research. This philosophy aims to identify and assess the cause that influences outcomes generally via experimentation. Other elements of this paradigm include observation and measurement of a phenomenon. The study design of a post-positivist research generally begins with an evaluation of the theory and is then followed by collection of numerical data, which determine the acceptance or refusal of the initial theory.

  Creswell, (2014), expands on this explanation by outlining the following steps within post positivist research:

    - Determination: establishing the cause(s) of an effect or outcome,
    - Reductionism: reduce and assembling a list of testable causes,
    - Empirical observation and measurement: the collection of data which observe the causes established,
    - Theory verification: the testing and processing of the data collected,

- Research: further refining of theory verification by implanting a comparison between the data collected and established data,
- Finalisation: development of relevant and true statements (Creswell, 2014).

The current research therefore has a post-positivist approach as it incorporates all the systems and steps outlined by Creswell, (2014), and Bryman, (2016). For the current research, this framework provided a congruent approach to scientific research, and emphasized:

- the importance of reflexivity (the reflection of the researcher's own beliefs, biases, and assumptions that may influence their research),
- the recognition of the limitations of objective observation,
- the importance of critical reflection and revision.

By adopting this approach, the current researcher developed a more nuanced understanding of the complex and dynamic nature of the phenomenon being observed.

Finally, the post-positivist approach allowed the researcher to recognise the tentative nature of scientific claims and how these claims are subject to revision based on new evidence. Post-positivists contend that scientific knowledge is an ongoing process of inquiry and refinement, never complete or final (Creswell, 2014).

3.7. List of Participants

Following approval from FREC and UREC, participant recruitment was carried out with the aid of an intermediary, who for this study was the University of Malta Registrar. A convenience sampling approach was utilised in this study for the recruitment of participants. This system permits an inexpensive, and efficient recruitment system which allowed for an easy collection of data (Hogan, et al., 2009). The reason why it is convenience sampling, rather than any other type of sampling, is due to the fact that the University Registrar utilised a system with a readily available population, i.e. the students at the University of Malta. Subsequently, referral sampling was also conducted as the Registrar disseminated the current research via its university portal (an introductory e-mail). Thus, interested potential candidates (who met inclusion criteria for the study), were able to reach out to the researcher and be recruited.

In the introductory e-mail/recruitment letter (*Appendix Form 1)*, the participants were thoroughly briefed about the experimental procedures of this study and signed written consents were requested. The participants who consulted the introductory e-mail contacted the researcher via the e-mail address or mobile number which were included in the introductory e-mail.

At the end of the data collection timeframe, a total of 40 subjects had qualified and participated in the study. This was ideal, as the original goal was to recruit 40 participants. The rate at which subjects were admitted into the study varied periodically. External factors which influenced subject rate of recruitment included: examination periods (June–July and August–September); Vacation periods (July – August); and a resurgence in COVID cases (May – August 2022).

3.7.1. Inclusion criteria were:

- age range 18-30 years;
- ability to mobilise independently;
- **Sedentary individuals**: those participants not attending a gym, classes or participating in organised sporting activities. Sedentary individuals also included people who have a very low-intensity activity at their respective workplace;
- physically **Active individuals**: those participants attending a gym, classes or participating in organised sporting activities. Active individuals also included people who have moderate- to high-intensity activity at their respective workplace.
- Provided informed consent

3.7.2. Exclusion criteria were:

- previous medical history with any peripheral and/or central neurological conditions;
- pre-existing conditions that may alter sensory perception;
- history of acute lower limb orthopaedic conditions that could affect the participant's ambulatory performance;
- blindness or severe visual impairments;

- severe cognitive impairment that prohibits the participant's comprehension during interventions;
- Carcinoma (CA) related pathology;
- Severe cardiorespiratory conditions that may be the primary cause of reduced mobility;
- Participants who disregarded the instructions within the information letter, example:
    - Participants who consumed heavy meals prior to the session;
    - Participants who consumed caffeine prior to the session.

3.8. Research Tools and Data Collection

3.8.1. Overview

The entire research protocol was performed in the clinical gait and motion analysis laboratory in the Podiatry Department, within the Faculty of Health Sciences (University of Malta, Mater Dei Hospital). An 18-camera Vicon Motion Capture System was utilised to collect all gait parameters. Retroreflective markers were placed upon various key locations on the participants' lower limbs using medical grade tape as dictated by the Plugin-Gait model (Vicon). This system provided a digital map of the participants' walking pattern in space whilst also providing quantifiable data which was then used to measure pattern differences. The methodology adopted within the current study was performed and conducted by the principal investigator who is an experienced physiotherapist and gait analyst. Participants were instructed to wear shorts or leggings and to bring comfortable footwear. The commencement of the data collection session included: an introduction session; anthropometric data recording; and marker placement. All 40 participants were asked the same questions and the same readings were taken throughout. The next part of the data collection session included the calibration and the initial motion capture. Here participants were instructed to walk at a self-selected, comfortable pace along an 8m walkway (Alnahdi, et al., 2014). Numerous captures were taken to make sure a "good trial" could be selected (refer to Section 3.8.8.). After the initial motion capture, participants were asked to run/jog on a treadmill also at a self-selected, comfortable pace whilst having their relevant recordings of Rate of Perceived Exertion (RPE), speed, distance, time, peripheral oxygen saturation (SPO_2), and Heart Rate (HR) tabulated. Once fatigue was achieved (when the participants stated that they scored their fatigue as 20 on the RPE scale), the participants were required to perform one final motion capture with the same instructions as the earlier gait analysis procedure. Subsequently, the six best pre- and post- trials (three for pre- and three for post-) with the most representative gait patterns were selected from each session and used for data processing (further explanation of the representative gait selection process shall be outlined in Section 3.8.8.). In data processing, the captures were tabulated and an average was calculated. This entire process was conducted for all 40 participants and spanned over a period of 6 months and was conducted in a safe environment. No harm was envisaged and no harm befell any of the subjects who participated in this study. Participant safety was paramount and breaks were allowed as necessary, and the session resumed upon request.

3.8.2. Data collection session

Research instruments used were:

- 12 Infra-Red: Bonita, (Vicon);
- 6 infrared Vantage cameras (Vicon);
- 2 Force plates: AMTI - Optima;
- Digital scales with stadiometer;
- Pulse-Oximeter (Gima, OXY-5 Finger Oximeter);
- 18 Retroreflective markers;
- La Fayette anthropometer;
- Vicon Nexus 2.14.0x64 + Vicon Polygon 4.4.6 running on a Windows PC.

Preparation work included:

- Preparation of documentation: hardcopy version of information letter, consent form, Data sheet;
- Vicon Nexus tested for capture;

- Cameras and Force plates calibrated;
- Preparation of markers;
- Walkway cleansed and sterilised;
- Apparata (Digital scales and Pulse-Oximeter) cleansed and sterilised;

  Temperature setting.

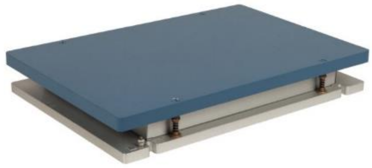
12 Infra-Red: Bonita, (Vicon)	 (Vicon, 2023)
6 infrared Vantage cameras (Vicon)	 (Logemas, 2023)
2 Force plates: AMTI - **Optima**;	 (AMTI, 2023)
Digital scales with stadiometer;	 (HIWEIGH, 2023)
Pulse-Oximeter **(Gima, OXY-5 Finger Oximeter)**;	 (GIMA, 2023)
18 Retroreflective markers	 (B&L, 2023)
La Fayette anthropometer	 (Bravo, et al., 2018)

Figure 3.1.: Diagrammatic representation of the apparata used.

3.8.3. Psychometric scales

Rate of Perceived Exertion Scale (RPE), is a validated, widely accepted psychophysical tool that aids the assessing of perceived exertion for a variety of exercise types. RPE is a simple test which, as described in the previous sections, is a scale that ranges from six to twenty that classifies exercise intensity (Scherr, et al., 2013). RPE scores were found to be positively significant in numerous studies. In a study conducted by Pollock, et al. (2013), it was found that the RPE was a reliable indicator of physical fatigue which had positive relationship with heart rate measurements (r = 0.32) (Pollock, et al., 2013). Studies which delved into the reliability of RPE in the fatigueability of participants during treadmill walking / running, resulted in a reliability reading of *r* = 0.58–0.90 (Chen, et al., 2002) (Karavatas & Tavakol, 2005).

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Figure 3.1: Table of Borg RPE scale (adapted from (Hodges, 2013))

3.8.4. Anthropometric measurements

Anthropometric data forms part of the profiling of the participants within the context of the study. It also provides parameters to be used within Vicon Nexus 2.14.0x64 during data capturing. After the questions within the Data Sheet were answered, the anthropometric data of each participant was collected and inputted within the "Subject field" of Vicon Nexus. The data included:

- Weight (Kg);
- Height (mm);
- Leg Length (mm);

- Inter ASIS distance (mm);
- Knee width (mm);
- Ankle Width (mm).

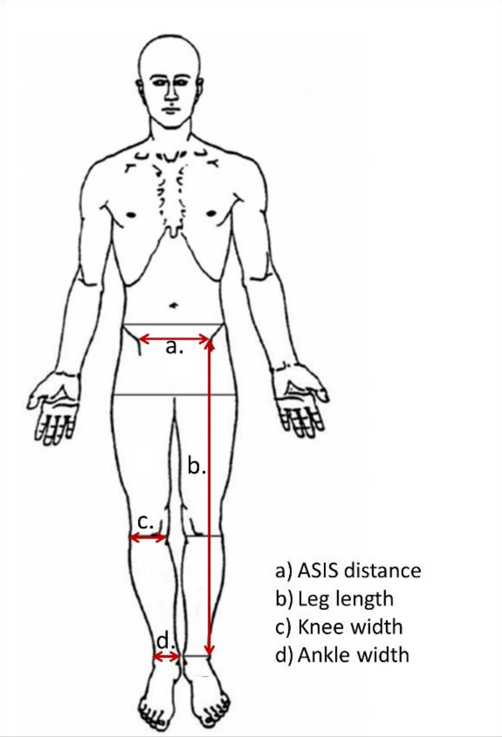


Figure 3.2: Diagram of how anthropometric data was measured (adapted from Loh & Zulkifli, (2018))

Once inputted, the anthropometric measurements prompted Vicon Nexus to calibrate the measurements with the markers placed on the subjects according to the Static Plug-in Gait Model. This allowed the researcher to track the markers' location in real-time and gather kinetic data from force-plates.

3.8.5. Marker placement

As outlined previously, Vicon's three-dimensional (3D) gait analysis, *r*equires the use of markers which would allow Nexus **2.14.0x64** to geo-track the individual's movements. In this study, 18 12mm polypropylene retro-reflecting spherical markers were attached to the skin/clothes, using double-sided medical-grade tape, according to the lower-limb Plug-in Gait

Model (PiG). Subjects had been asked to wear either shorts or leggings as these would allow effective marker placement. Model marker placement was organised as follows:

Table 3.1: Marker mapping and placement

Markers (placed in twos for left and right)	Location of placement (refer to Figure 1 below)
1, 2	Posterior Superior Iliac Spine (PSIS) – placed directly on the anatomical structure.
3, 4	Anterior Superior Iliac Spine (ASIS) – placed directly on the bony prominence of the ASISes
5, 6	Hip – placed along the lateral aspect of the thigh. Marker selected was not the standard "button marker" but rather a "wand marker".
7, 8	Knee – placed along the lateral border of the knee joint-line.
9,10	Tibia – placed along the lateral aspect of the shin area with another wand marker.
11, 12	Ankle – placed on the bony prominence of the lateral malleolus.
13, 14	Heel – placed on the Achilles tendon insertion.
15, 16	Lateral malleolus – placed on the bony prominence of the layeral malleolus.
17, 18	Toe – placed on the web between the first and second toe.

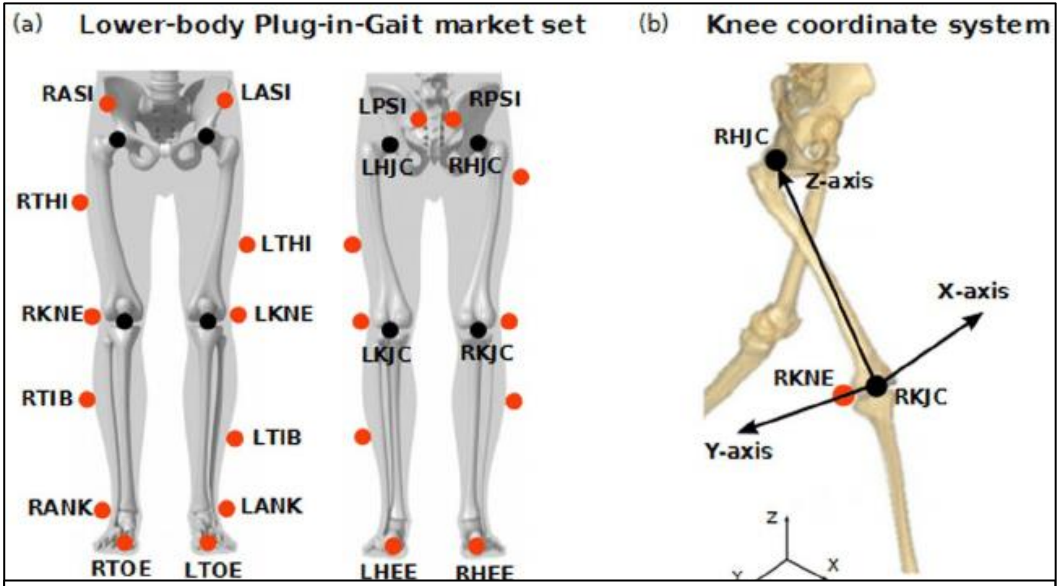


Figure 3.3: A representation of the locations where the reflective markers were placed, in accordance with the plug-in gait model (adapted from (Baudet, et al., 2014)

3.8.6. Vicon Measurements

In view of the aforementioned expected outcomes, the following variables were collected from the Gait Analysis sessions:

Kinematic readings: Pelvic movements; Hip movements (flexion, extension, abduction, adduction); Knee movements (flexion and extension); Ankle movements (dorsiflexion, plantarflexion, eversion, inversion).

Kinetic readings: Forces and moments of all the aforementioned movements (Pelvic, hip, knee, ankle).

Gait Spatio-Temporal readings: Step Length; Step Width; Stride Length; Cadence; Step Time; Stride Time; Stance Time; Swing Time; Single Support Time; Double Support Time; Gait Speed; Stride Speed.

3.8.7. Data Capture and Processing

Data collection occurred at the Clinical Biomechanics Laboratory at the Faculty of Health Sciences (University of Malta, Mater Dei Hospital). Upon entering the Clinical Biomechanics Laboratory, the following COVID measures were adopted:

- The researcher wore a face-mask at all times;
- Participants wore face-masks when anthropometric data and questions were put forward;
- Participants were able to remove the face-mask when performing the intervention and carrying out the Vicon Motion Capture data collection so that results could be realistic;
- Social distancing best practises were maintained;
- Two persons only were allowed inside the lab during a data collection session.

The participants were asked a series of questions (delving into the participants' quality of life) and anthropometric data was collected (refer to Appendix Form 3). The questions put forward to the participants were related to the participants' profession, lifestyle, and sport performance. Personal data was pseudonymised.

Upon examination, reflective markers were placed according to the Plug-in-Gait model (Vicon, UK) across all the joints of the lower limb (Figure 3.3). Static captures of the participants were taken at the beginning of every capture session. This allowed for the calibration, labelling and reconstruction of the subsequent participants' dynamic captures. The participants were requested to walk (with adequate sports footwear such as trainers) at a self-selected comfortable pace on an 8-metre walkway where their actions were captured by an 18-camera Vicon Motion Capture System. Every 8m walk on the aforementioned walkway equated to a trial. The participants were instructed to perform twenty captures (walking the entire length of the 8m walkway constituted one capture) from which three good trials were selected. In accordance with GDPR guidelines, no live video captures of the individuals were taken. Furthermore, each individual's mapping was given a code number instead of the participant's particulars. After this initial phase, the markers were left in place for the duration of the rest of the session in order to minimize human errors of marker re-application.

During the next phase of the session, the participants were then asked to walk or jog on a treadmill at a self-selected pace until they scored 17 on the Borg's Rate of Perceived Exertion Scale (RPE). Participants were instructed to maintain the inclination of the treadmill at 0^o to maintain a standardised set of results. HR, SPO_2, Distance travelled, RPE score and time were collected during this period of the session. Participants were allowed to change the speed of the treadmill either by adding or subtracting it. Furthermore, subjects did not receive any bias or extra coaxing/motivation to maximise performance. Once fatigue was attained, the last recordings were captured and the participants were promptly instructed to walk on the 8m walkway as before. Again, 20 laps were carried out, and a final static trial was repeated at the end of the session to ensure that markers did not displace.

Figure 3.4: Setup at Clinical Biomechanics Lab at the Faculty of Health Sciences.

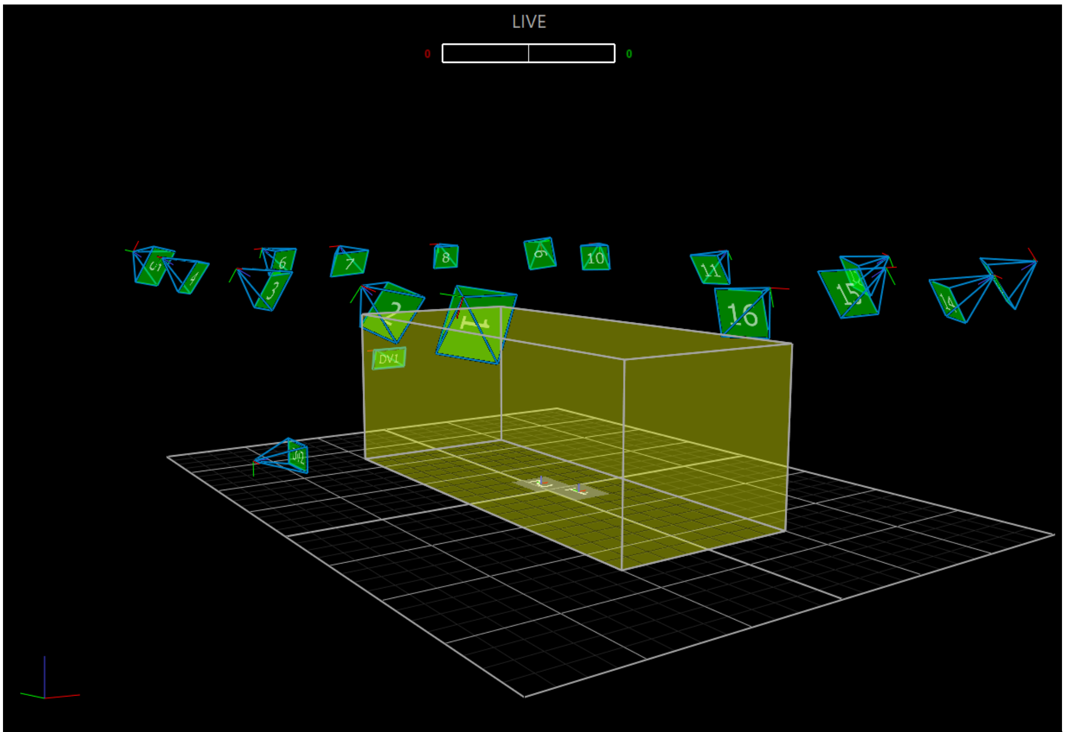


Figure 3.5: Vicon Setup at Clinical Biomechanics Lab at the Faculty of Health Sciences including the capture volume (represented in yellow box).

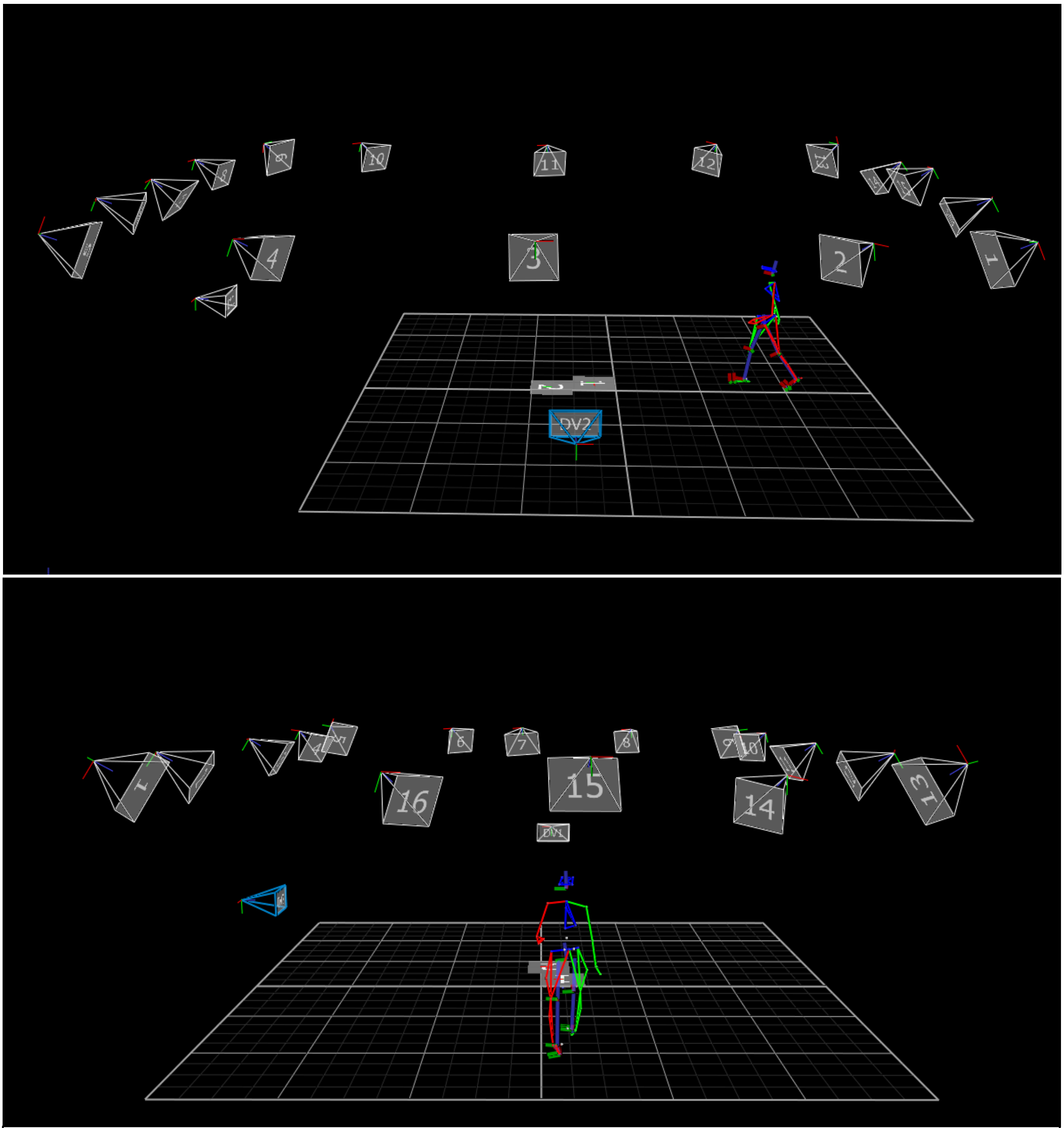


Figure 3.6: Vicon Setup at Clinical Biomechanics Lab at the Faculty of Health Sciences with a rigged participant lateral view (top) and front view (below).

3.8.8. Processing Routine

- **Reconstruction and Labelling of subject markers**

The raw data captured did not immediately illustrate either the marker locations or the body skeleton of the participant walking during the capture. Therefore the first level of processing, involved the Vicon Nexus illustrating the markers on-screen, labelling them and rigging them onto a human skeleton in a similar fashion as F*igure 3.3*. This allowed the researcher to examine the captured data as demonstrated on *Figure 3.4*.

- **PiG Model incorporation**

The next step after the reconstruction and the labelling of the markers, was the integration of the PiG model on the skeleton.

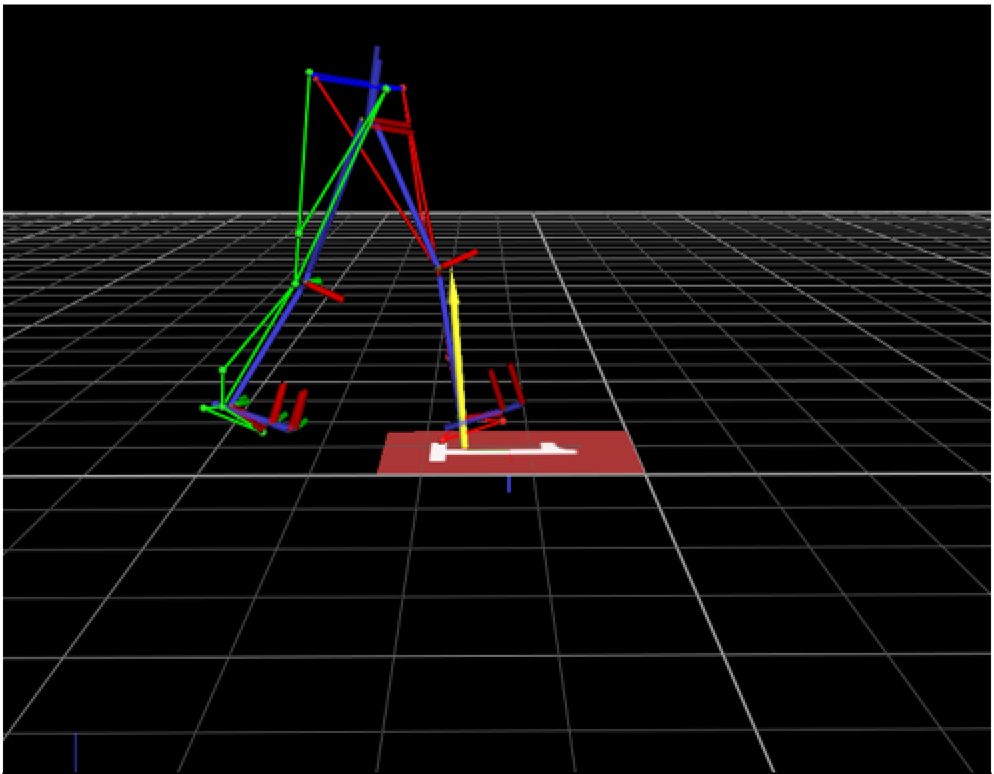


Figure 3.7: Represents the mapping data which was captured by the 18-camera Vicon Motion Capture system. Image illustrates the mapping points of the lower-limb from the pelvis-downwards of both lower-limbs (adapted from (Liaison, 2019)

- **Event selection**

The final cutting of the trial involved the trimming of the trial to illustrate only the events on the force-plates. This included the heel strikes and toe-offs which occurred at the two force-plates alongside the remaining swing phase beyond the force-plates. This was done so that only one cycle per lower-limb was retained; and so that only the data from the period of constant velocity was maintained. Furthermore, heel-strikes and toe-offs were time-stamped on the time bar at the bottom of the capture.

- **Gap filling**

Another part of the data interpretation included gap filling. Gaps are instances within the gait capture where markers were concealed either because of clothing obstruction, arm swing, or when one leg eclipsed the other leg's markers. These gaps are discerned and viewed within Vicon Nexus and are fixed either manually or automatically with the use of pattern 'predictors'. Gap-discerning helped in the selection of final captures as gaps that lasted for more than 15 frames were excluded. Gap filling in this research was performed with the ***automatic-pattern-prediction*** option, but then checked by the researcher. There are various patterns that can be utilised for gap filling for various scenarios, these include:

  - **Cyclical fill**: if the gap was situated on a limb at any stage of the gait cycle;
  - **Pattern fill**: for lengthy gaps which needed to follow the same trajectory from a previous cycle;
  - **Rigid body fill**: for any gaps situated at the pelvis.

- **Trial selection**

As mentioned in the previous point, only six captures were selected per individual. The selection of the best trials constituted:

  - Unbiased/natural gait from the participants (initial captures were biased as participants wanted to perform as best they could);
  - Events on at least one of the two force plates on the walkway;
  - No lengthy marker gaps;
  - No abnormal data.

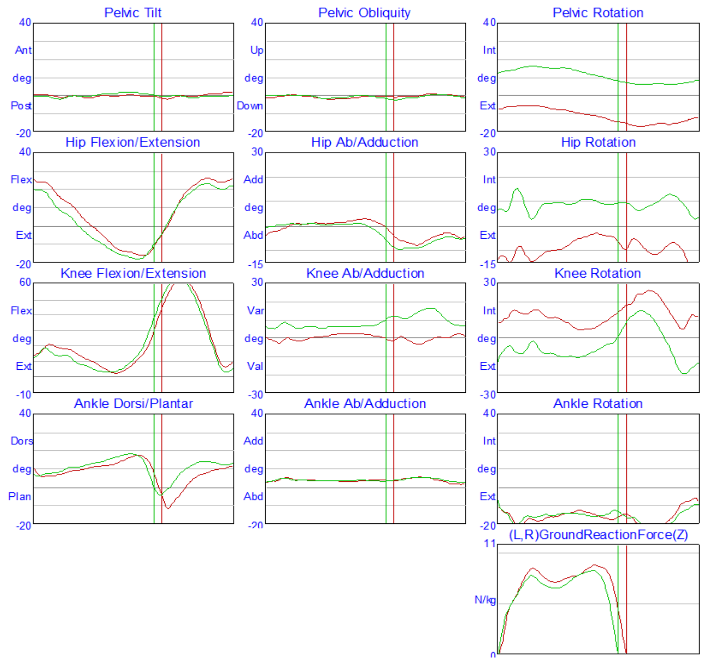
Once the optimal trials were selected, they were saved as .c3d files and could thus be exported into Vicon Polygon.

- **Vicon Polygon Version 4.4.6**

Vicon Polygon is a software by which data can be computed into tabular and graphical formats. This was achieved by importing the six selected trials into a new Vicon Polygon Report. For this study, **Version 4.4.6** of this software was used. The programme presents numerous categories of data which can be extrapolated from a single trial. The data selected for this research consisted of the:

- kinematic data along the x-, y-, and z- axis of the pelvis, hip, knee, and ankle,
- kinetic data along the x-, y-, and z- axis of the GRF,
- Spatio-Temporal parameters of the various events of the gait cycle.

The above data resulted in a data sheet of fifteen graphs per trial (dubbed Polygon data sheet). Thus, initially, every participant had six Polygon data sheets which amassed to ninety graphs. These were filtered to provide a more holistic representation of the participants' gait,



TEMPORAL PARAMETERS		
Cadence average both L.L.s	101 steps/min	
	Left	Right
Cadence	98.6 steps/min	104 steps/min
Limp Index	1.14	0.97
Step Length	0.63 m	0.65 m
Step Time	0.55 s	0.60 s
Step Width	0.17 m	0.23 m
Stride Length	1.23 m	1.26 m
Stride Time	1.22 s	1.15 s
Walking Speed	1.01 m/s	1.10 m/s

Figure 1.8: A representation of a Vicon Data Sheet.

by focusing on average readings which were generated within the Vicon Polygon programme. Thus two Polygon data sheets were collected from a single participant (pre– and post–fatigue). If left with its default settings, Polygon would generate graphs with 1,000 sample points, resulting in graphs which contain 450 columns. Such depth of detail was not required so the sample points were reduced to 51, which in turn generated 50–columned–tables. Graphs and tables were then copied onto the clipboard and pasted onto a Microsoft Excel Workbook.

- **Microsoft Excel**

Microsoft Excel **(Version 15.05545.1000)** is an analytical software whereby data and statistics can be analysed with the use of spreadsheets and its subsequent tools. In this study, the results obtained from Polygon along with the data captured during the treadmill session were presented and tabulated. As explained before, the Polygon data sheets extrapolated from the trials, were pasted into Excel in their graphical as well as in their tabular format. Meanwhile, the results collected from the Data Sheet document (Appendix Form 3.: Data Sheet Sample), were inputted manually per individual. Each individual was assigned his/her own worksheet, which totalled to 40 Excel worksheets. Another Excel worksheet was generated in which the data from all the participants' worksheets were amalgamated into various tables representing the various variables of the study. This allowed for the efficient generation of tables which were used to examine the correlations and relationships between variables.

Phase labelling

This phase of the Data Analysis process was conducted in Microsoft Excel. The kinematic and kinetic data accumulated from Vicon Polygon were presented in a tabular format in Excel, and the five observable phases of gait were labelled: Heel Strike, Mid-stance, Weight-transference, Toe-off, and Mid-swing. This was achieved by observing the GRF (Z) graph, and selecting the relevant crests and troughs which represent the five phases of a gait cycle (Figures 3.6 and 3.7). The initial selection of these points was conducted on the GRF (Z) table, and the corresponding kinematic and kinetic data along those five instances were selected for each lower limb of every participant's pre and post readings.

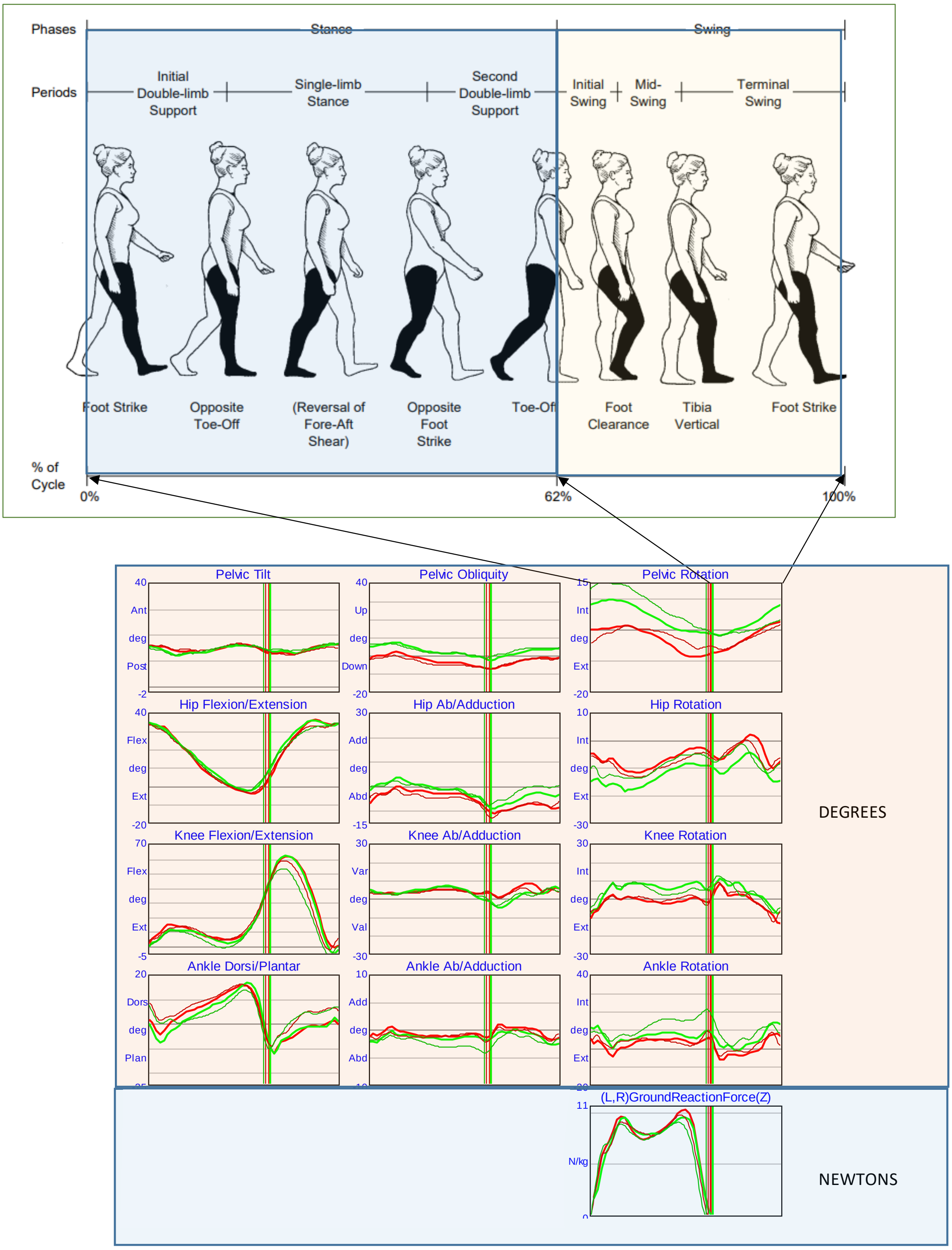
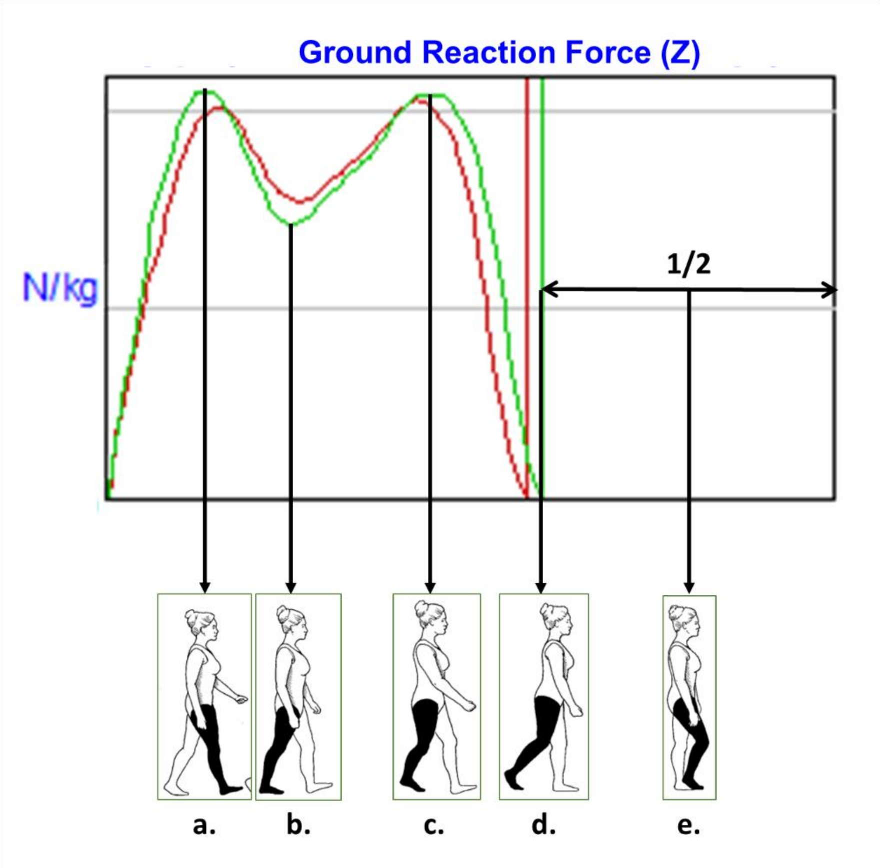


Figure 3.9: Diagram illustrating the phases of gait and where they are represented in the Polygon-generated graphs.



a) Heel Strike
b) Mid-stance
c) Weight Transference
d) Toe-off

Figure 3.10: Diagram illustrating the different key points indicative of the five instances of gait and where they are represented in the Polygon-generated graphs.

- **SPSS**

SPSS (Statistical Package for the Social Sciences) Version 26, Release 26.0.0.0. is another analytical software widely used to organize, analyse, and interpret data in various fields. SPSS offers a user-friendly interface that allows researchers to input data in different “variable columns” and perform various statistical analyses, such as descriptive statistics, inferential statistics, correlation analysis, regression analysis, factor analysis, and more. The current study has made use of various statistical tests available in this software to explore relationships between variables, identify patterns and trends, and draw conclusions based on the data collected. The programme can also represent data in a graphical format. This too has been used in the current study. A detailed rendition of the tests performed can be read in the section below.

3.9. Data Analysis

As discussed in the previous section, six captures were kept per individual. With the captures selected the following correlations and data trends were analysed:

- Vicon Data
  - Captures Pre Vs Captures Post (Paired Samples T test). Comparison of mean pre- and post- kinematic and kinetic readings of all participants, active participants, and sedentary participants at:
    - Heel Strike
    - Mid-stance
    - Weight-Transference
    - Toe-Off
    - Mid-Swing
  - Spatio-Temporal Readings pre- and post- (Paired Samples T test)
    - All participants
    - Active participants
    - Sedentary participants
  - Heart Rate scores: Comparison of participants' mean pre- and post- Heart Rate Scores (Paired Samples T test)
  - RPE relationships
    - RPE Vs HR
      - Correlation of RPE and their corresponding HR scores of all, active, and sedentary participants (One Way ANOVA)
      - HR against RPE Pearson Correlation Test
      - HR against RPE for Active and Sedentary Participants
    - Speed vs RPE
      - Correlation of RPE and their corresponding Speed scores of all, active and sedentary participants (One Way ANOVA)
      - Speed against RPE along with Pearson Correlation Test
    - SPO_2 vs RPE

  - Correlation of RPE and their corresponding SPO_2 scores of all, active and sedentary participants (One Way ANOVA)
  - SPO_2 against RPE Pearson Correlation Test
  - SPO_2 against RPE for Active and Sedentary Participants

- Distribution of data: the Shapiro-Wilk Test was used to examine the distribution of the data collected. As the data collected was normally distributed, the parametric Independent Samples T-Test was utilized for the comparison between two sample means from unrelated groups (e.g. Active Participants' data vs Sedentary Participants' data).
- Active vs Sedentary (Independent Samples T-test). Comparison of change in mean scores of kinematic and kinetic data (post scores minus-pre scores) between Active and Sedentary participants during:
  - Heel-Strike
  - Mid-Stance
  - Weight Transference
  - Toe-off
  - Mid-Swing

For the above correlations to be performed, SPSS was used. The subsequent section analyses the tests and correlations used for the extraction of results from the data collected.

3.9.1. Pre Vs Post readings

The Paired Samples T-test was used to compare mean pre-scores with mean post-scores. The null hypothesis specifies that the mean scores vary marginally between the two sessions and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean scores vary significantly between the two sessions and is accepted if the p-value is smaller than the 0.05 criterion.

3.9.2. Relationship between RPE and test measures

The One Way ANOVA test was used to compare mean heart rates between different RPEs. The null hypothesis specifies that the mean heart rates vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

3.9.3. The strength of the relationship between RPE and test measures

The Pearson correlation coefficient measures the strength of the relationship between two continuous variables and it ranges from -1 to 1. A correlation coefficient close to 1 indicates a strong positive relationship between the two variables; a correlation coefficient close to -1 indicates a strong negative relationship; while a 0 correlation coefficient indicates no relationship between the two variables. The null hypothesis specifies that there is no relationship between the two variables and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that there is a significant relationship between the two variables and is accepted if the p-value is less than the 0.05 criterion.

3.9.4. Active vs Sedentary

Considering the normative distribution of the data collected, the Independent Samples T-test was used to analyze and compare the change in data results between the two separate groups of active and sedentary individuals. For the Vicon data, the score difference was computed for all movements of each participant by subtracting the pre-score from the post-score. A positive score difference indicates that the post score is larger than the pre-score; while a negative score difference indicates that the post score is smaller than the pre-score. The null hypothesis specifies that the mean score differences vary marginally between the two groups and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean score differences vary significantly between the two groups and is accepted if the p-value is smaller the 0.05 level of significance.

3.10. Validity and Reliability of data

The validity of a scientific study refers to how well the study measures what it is intended to measure and whether the study's conclusions are supported by the data collected. In other terms, validity is the degree to which a study accurately reflects reality (Creswell & Plano Clark, 2018).

Creswell, (2014), outlined that there are several categories of validity adopted within a scientific study, these include:

1. **Internal validity** is the accuracy with which a study measures the relationship between variables within the study. A study with high internal validity is able to exclude alternative explanations for the observed results and, as a result, is more likely to be accurate (Creswell & Plano Clark, 2018). A clear example is the observation made with regards to the positive relationship between RPE and HR scores (Babbie, 2016). The internal validity lies in the fact that after performing fatigue-inducing exercise, the participants demonstrated high HR scores in their post- readings in comparison to their pre-fatigue scores .
2. **External validity** is the extent to which the findings of a study can be applied to other populations or contexts. A study with high external validity is more likely to generate generalizable findings (Creswell, 2014). The external validity of the current study is high as observations made in the current study are representative of a general "normal" (without any diagnosed medical conditions) population and thus the current findings can be used as comparative data for similar researches.
3. **Construct validity** refers to the extent to which a study's measures accurately reflect the constructs or concepts being investigated. An investigation with high construct validity measures what it purports to measure (Creswell, 2014). In the case of the current study, an example would be whether the RPE scale is actually measuring physical lower limb fatigue and not other types of fatigue, like cardiovascular fatigue.
4. **Face validity** refers to whether the measures of a study "appear" to gauge what they are intended to measure (Creswell & Plano Clark, 2018). Face validity is a subjective evaluation and is not inherently indicative of the validity of a study as this phenomenon quite often relies on visuals and whether "things look like" they're working the way they should (Babbie, 2016). Without the use of anatomical landmarks, lower limb dimension measurement and marker placement, the current study would have relied only on face validity, which is not the case.

5. **Content validity** refers to the reliability and validity of the apparata used to measure the construct or concept under investigation (Creswell, 2014). This validity relies on the accuracy of the measurement tools adopted within the study. In the current study one could mention:
    a. **Vicon Motion Capture system**: The system used in the current study is highly advanced and accurate. The tracker software used in conjunction with the Vicon motion capture system was the Vicon Nexus **2.14.0x64** software running on a Windows PC. This system is considered as the optimal setup and is also used to test and validate modern technologies (Castelli A., et al., 2015).
    b. **Bonita Infrared cameras**: Each camera had its own emitting source and delivered a grayscale image with VGA resolution up to a 250 Hz frame-rate. The camera system was measured to have an accuracy of 63 [±5] micrometres with only four of the eighteen cameras switched on. These devices frequently get software updates making them even more valid and reliable.

To determine the validity of a scientific study, it is necessary to take each of these categories of validity into account. To increase the validity of their studies, researchers employ a variety of methods, such as controlling external variables, employing appropriate measures and methods, and selecting a representative sample.

3.11. Conclusion

This chapter has outlined the experimental procedure of how data was collected for this study, and how the researcher abided by the various ethical considerations, principles for a safe and ethical data collection, and the philosophical paradigms involved. The strengths and weaknesses of this methodology have also been discussed and analysed. The subsequent chapter is a platform from which the measurements, readings, variables and correlations collected can be viewed.

Chapter 4: Results

4.1. Introduction

The results chapter of this study encompasses the findings of the research in a clear and concise manner. This section describes the data collected during the study and analyses the data using appropriate statistical methods. The purpose of the results chapter is to answer the research question and hypotheses and to provide a comprehensive understanding of the study's findings.

This chapter will begin by providing examples of the data collected per individual, including their Vicon Capture data and the spatio-temporal parameters collected during the data collection session.

The analysis of the data is the most critical part of the results chapter. The statistical analysis methods used are described in detail for every relationship observed. Descriptions included the tests used, any assumptions made and any corrections applied. The results are presented in a clear and organized manner, with tables and figures illustrating the key findings.

The results address the research question, with each finding supported by statistical evidence collected during the current research's data collection session. The results are presented objectively, without any interpretation or discussion as the "Discussion Chapter" shall delve into the discussion.

Finally, this chapter summarizes the study's main findings, highlighting the most important results and their significance.

4.2. Demographics

A total of forty participants fitted into the inclusion and exclusion criteria discussed in chapter 3 and successfully participated in this study to form two groups,

- Active participants: 31
- Sedentary participants: 9
- Male Participants: 20
- Female Participants: 20
- Age: average: 26; standard deviation: 2.05
- Weight (Kilograms): average: 69.02; standard deviation: 16.14
- Height (metres): average: 1.68; standard deviation: 0.11
- BMI: average: 24.29; standard deviation: 4.03

The relevant demographic data (quality of life: sedentary/active) to the purpose of this study was retrieved from the Data sheet (Appendix Form 3) of each participant taking part in this study.

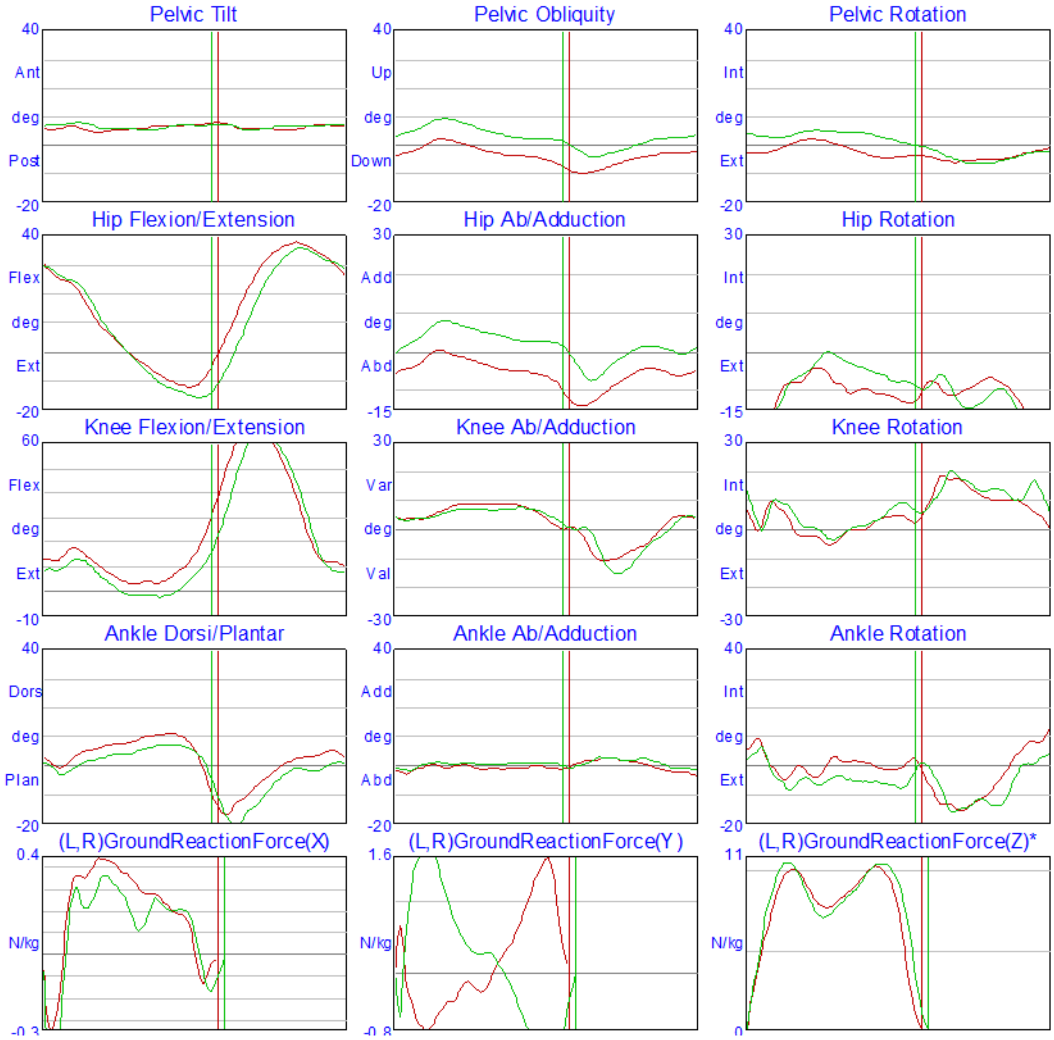
4.3. Examples of the Data collected per individual

Example of the Raw Kinematic and Kinetic Data from Vicon Polygon (imported to Microsoft Excel).

Kinematic	Movement	Degrees																																																		
LPelvisAngles	flexion/extension	6.3	6.05	6.1	6.42	6.77	6.9	6.58	5.83	5.06	4.8	5.06	5.49	5.8	5.99	6.11	6.24	6.38	6.52	6.72	6.96	7.11	7.12	7.11	7.19	7.31	7.44	7.64	7.94	8.23	8.35	8.03	7.35	6.66	6.32	6.33	6.48	6.57	6.48	6.24	5.94	5.73	5.74	6.04	6.52	7.02	7.36	7.46	7.35	7.15	7.08	7.26
RPelvisAngles	flexion/extension	7.19	7.31	7.44	7.63	7.92	8.22	8.35	8.09	7.44	6.73	6.33	6.31	6.46	6.56	6.51	6.3	6.01	5.77	5.72	5.94	6.37	6.88	7.28	7.45	7.4	7.21	7.07	7.16	7.43	7.65	7.7	7.45	6.84	6.11	5.73	5.85	6.13	6.4	6.63	6.78	6.86	6.89	6.88	6.86	6.9	7	7.1	7.24	7.36	7.4	7.44
LHipAngles	flexion/extension	30.6	28.6	26.6	25.4	24.9	23.7	21	17.5	13.8	10.8	8.42	6.27	4.14	2.03	0.14	-1.51	-3.14	-4.46	-6	-7.43	-8.66	-9.73	-10.7	-11.5	-11.9	-11.8	-10.5	-7.8	-4.1	-0.058	4.21	8.62	13.3	18.1	22.6	26.6	29.9	32.5	34.5	36	37.2	38.1	38.3	37.9	36.9	35.7	34.6	33.3	31.4	29.3	27.3
RHipAngles	flexion/extension	30.5	29.5	28.1	26.6	25.6	25	23.7	21.1	17.6	13.7	10.3	7.55	5.06	2.51	0.12	-2.09	-4.21	-6.26	-8.18	-9.93	-11.3	-12.3	-13.2	-13.9	-14.6	-15.2	-15.7	-15.2	-13.6	-10.7	-6.93	-2.84	1.5	6.18	11.5	16.7	21.1	24.9	28.2	31.1	33.4	35.1	36.1	36.3	35.7	34.4	33.1	32.2	31.5	30.4	29.1
LKneeAngles	flexion/extension	13.6	13.4	12.9	14.2	17	18	17	15.1	12.9	11.2	9.49	7.68	6.16	4.8	4.1	3.99	3.86	4.43	4.15	4.09	4.75	6.21	7.83	9.58	11.8	14.9	19.1	25.1	32.2	39.9	47.6	55	61.2	65.2	67.4	68.1	67	64.5	61	56.5	51.3	45.2	38.1	30.3	22.7	16.6	13.3	12.2	12	11.9	11.2
RKneeAngles	flexion/extension	9.02	9.31	9.14	9.27	11.1	13.1	13.6	12.4	10.2	7.79	5.54	3.82	2.08	0.19	-0.98	-1.36	-1.38	-1.31	-1.36	-1.63	-1.52	-0.91	0.15	1.89	4.16	6.67	9.28	12.6	17.1	23.1	30.7	38.9	47	54.7	60.5	63.5	64.4	63.8	62	59.2	55.5	50.6	44.6	37.4	29.1	20.9	14.4	10.8	9.05	8.15	8.28
LAnkleAngles	flexion/extension	2.84	1.93	0.033	-0.26	1.2	2.98	4.58	5.37	5.82	6.38	6.97	7.48	7.68	7.76	8.12	8.89	9.74	10.4	10.7	11	11.3	11.5	11.2	10.4	8.8	6.15	1.73	-4.02	-10	-14.4	-16.7	-15.6	-12.7	-11.3	-9.68	-7.31	-5.47	-3.85	-2.16	-0.34	1.07	1.91	2.68	3.16	3.23	3.6	4.3	5.21	5.56	4.81	3.39
RAnkleAngles	flexion/extension	1.31	0.38	-1.01	-2.85	-1.92	-0.6	0.78	1.91	2.38	2.6	3.05	3.84	4.33	4.3	4.29	4.85	5.65	6.27	6.78	7.17	7.39	7.5	7.47	7.03	6.37	5.32	3.39	0.3	-4.64	-10.6	-15.8	-19.5	-21.6	-18.7	-15.4	-13.9	-11.7	-9.04	-6.59	-4.5	-2.7	-1.24	-0.39	-0.72	-1.69	-1.69	-1	0.22	1.11	1.57	0.98
LPelvisAngles	ab/adduction	-3	-2.79	-2.45	-1.8	-0.77	0.47	1.59	2.26	2.4	2.11	1.62	1.03	0.35	-0.37	-1.04	-1.61	-2.12	-2.55	-2.86	-3.07	-3.2	-3.29	-3.4	-3.65	-4.09	-4.66	-5.38	-6.33	-7.45	-8.53	-9.27	-9.52	-9.33	-8.88	-8.33	-7.66	-6.87	-6.06	-5.37	-4.81	-4.28	-3.75	-3.28	-2.94	-2.74	-2.63	-2.57	-2.51	-2.4	-2.23	-1.94
RPelvisAngles	ab/adduction	3.65	4.08	4.65	5.35	6.27	7.37	8.45	9.22	9.51	9.37	8.95	8.42	7.78	7.02	6.21	5.5	4.93	4.41	3.88	3.4	3.02	2.79	2.66	2.59	2.54	2.45	2.3	2.08	1.59	0.63	-0.79	-2.28	-3.36	-3.72	-3.43	-2.87	-2.31	-1.78	-1.15	-0.4	0.41	1.16	1.8	2.3	2.61	2.77	2.86	2.99	3.19	3.49	3.9
LHipAngles	ab/adduction	-5.7	-4.74	-4.19	-3.82	-3.03	-1.54	-0.1	0.59	0.45	-0.17	-0.77	-1.14	-1.49	-2.03	-2.62	-3.15	-3.65	-4.12	-4.42	-4.65	-4.85	-4.96	-5.02	-5.21	-5.64	-6.16	-6.86	-8.22	-10.2	-12.3	-13.6	-14.1	-13.7	-12.6	-11.4	-10.2	-9	-7.89	-6.91	-5.98	-5.09	-4.37	-4.05	-4.11	-4.5	-5.1	-5.73	-6.02	-5.7	-5.17	-4.85
RHipAngles	ab/adduction	-0.4	0.96	2.15	2.92	3.79	5.06	6.56	7.75	8.32	8.22	7.67	7.12	6.68	6.2	5.75	5.36	5.06	4.7	4.22	3.79	3.39	3.06	2.91	2.8	2.84	2.86	2.73	2.35	1.43	-0.31	-2.75	-5.14	-6.84	-7.11	-6.14	-4.49	-2.95	-1.82	-0.81	0.17	1.04	1.59	1.85	1.75	1.36	0.91	0.36	-0.21	-0.34	0.33	1.45
LKneeAngles	ab/adduction	4.66	4.07	4.23	4.45	4.04	4.47	5.47	6.21	7.07	8	8.89	9.25	9.15	9.13	9.14	9.19	9.3	9.25	9.33	9.37	9.23	8.69	7.94	7.09	6.06	4.56	2.85	1.4	0.79	1.06	0.82	-1.2	-5.06	-8.6	-10.3	-10.5	-10.1	-9.5	-8.47	-7.19	-6.24	-5.32	-3.89	-1.83	0.38	2.73	4.52	5.46	5.36	4.76	4.74
RKneeAngles	ab/adduction	4.8	3.84	3.53	4.07	4.32	4.36	4.85	5.54	6.05	6.62	7.34	7.81	7.93	7.82	7.59	7.46	7.39	7.43	7.62	7.74	7.93	8.06	7.89	7.54	6.82	5.89	4.83	3.54	2.23	1.13	0.7	0.91	0.59	-2.3	-7.17	-11.7	-14.2	-14.7	-14	-12.4	-9.91	-7.17	-5.02	-3.47	-1.95	-0.46	1.43	3.44	4.93	5.35	4.88
LAnkleAngles	ab/adduction	-1.6	-1.95	-2.39	-1.32	-0.4	-0.0064	0.64	0.45	-0.22	-0.38	0.079	0.47	0.33	-0.3	-0.88	-0.95	-0.68	-0.7	-0.76	-0.67	-0.61	-0.44	-0.24	-0.14	-0.15	-0.2	-0.39	-0.77	-0.78	0.014	0.84	1.64	2.4	2.45	2.59	2.96	2.84	2.46	2.18	1.95	1.66	1.06	0.45	-0.19	-0.88	-1.39	-1.93	-2.19	-2.07	-2.36	-3.01
RAnkleAngles	ab/adduction	-0.6	-0.84	-1.24	-1.07	0.17	0.72	1.12	1.56	1.26	0.87	0.7	1.04	1.21	1.07	0.76	0.62	0.71	0.83	0.91	0.98	0.99	0.97	1.06	1.1	1.21	1.37	1.36	0.92	0.16	-0.29	-0.041	0.64	1.32	2.46	3.16	2.97	2.83	2.69	2.32	2.26	2.52	2.71	2.58	2	1.01	0.19	-0.23	-0.23	-0.44	-0.74	-0.95
LPelvisAngles	rotation	-2.5	-2.65	-2.63	-2.38	-1.94	-1.28	-0.43	0.51	1.36	1.94	2.23	2.28	2.14	1.81	1.31	0.68	-0.0095	-0.73	-1.47	-2.21	-2.93	-3.53	-3.91	-4.04	-3.95	-3.75	-3.53	-3.28	-3.13	-3.24	-3.69	-4.31	-4.91	-5.34	-5.55	-5.53	-5.36	-5.16	-4.97	-4.84	-4.75	-4.68	-4.53	-4.2	-3.69	-3.08	-2.51	-2.04	-1.6	-1.07	-0.51
RPelvisAngles	rotation	4.04	3.95	3.76	3.53	3.29	3.13	3.22	3.63	4.24	4.84	5.3	5.53	5.54	5.39	5.19	5.01	4.86	4.77	4.7	4.59	4.32	3.86	3.27	2.69	2.2	1.76	1.28	0.73	0.22	-0.19	-0.6	-1.24	-2.2	-3.31	-4.29	-5.04	-5.58	-5.92	-6.07	-6.07	-5.91	-5.6	-5.19	-4.7	-4.13	-3.47	-2.8	-2.24	-1.92	-1.78	-1.74
LHipAngles	rotation	-17	-15.6	-14.6	-15.3	-16.2	-13.1	-9.32	-7.98	-7.81	-7.54	-5.88	-4.13	-4.04	-4.88	-6.65	-8.3	-8.82	-10.5	-10.1	-9.54	-9.62	-10.3	-10.7	-10.9	-11.5	-12.4	-12.8	-13.2	-12.5	-9.94	-7.72	-7.46	-9.19	-10.9	-11.2	-10.5	-9.76	-9.1	-8.18	-7.06	-6.59	-6.92	-7.8	-8.87	-10.7	-12.9	-15.9	-17.7	-17.4	-17.4	-17.7
RHipAngles	rotation	-24	-20.6	-18.1	-16.4	-16.1	-14.8	-11.5	-8.29	-6.83	-6.04	-5.01	-3.41	-1.35	0.13	0.079	-0.89	-1.89	-2.74	-3.35	-3.7	-4.41	-5.15	-5.52	-6.27	-7.22	-7.61	-7.55	-7.8	-8.7	-9.57	-9.15	-7.15	-5.75	-6.77	-9.94	-13	-14.4	-14.6	-13.9	-12.8	-11.3	-9.84	-9.46	-10.5	-12.8	-16.1	-19.9	-23.5	-24.7	-22.4	-19.4
LKneeAngles	rotation	7.05	3.31	-0.04	5.14	10.2	8.71	7.03	3.79	-0.35	-1.66	-1.39	-1.49	-2.23	-4.26	-5.14	-3.54	-1.45	0.77	0.42	0.32	0.93	2.7	4.16	4.88	5.18	5.65	5.11	3.5	2.96	5.66	9.49	14.5	19	18.5	17.9	18.3	16.8	14.7	13.2	12	11.2	10.3	10.4	10.3	10.4	10.2	8.94	7.03	5.84	4.04	1.06
RKneeAngles	rotation	13.5	8.06	2.14	1.88	8.41	10.7	9.68	8.67	5.47	2.6	0.9	1.29	0.36	-1.49	-2.9	-2.53	-1.02	0.53	1.36	1.76	2.38	3.1	4.31	5.83	7.8	9.34	9.76	8.77	6.92	6.42	8.25	11.2	13.5	18.5	20.9	18.8	17.4	16.6	14.5	13.8	14.4	14.7	14.4	13.1	11	10.7	12.8	16.5	16.1	11.6	7.19
LAnkleAngles	rotation	6.19	7.74	9.8	4.75	0.31	-1.6	-4.72	-3.78	-0.58	0.19	-2.01	-3.91	-3.2	-0.19	2.63	2.97	1.64	1.77	2.02	1.63	1.32	0.49	-0.45	-0.95	-0.91	-0.64	0.24	2.09	2.13	-1.69	-5.65	-9.47	-13	-13.2	-13.9	-15.5	-15	-13.3	-12	-10.9	-9.56	-6.72	-3.81	-0.71	2.63	5.09	7.64	8.87	8.33	9.69	12.7
RAnkleAngles	rotation	2.51	3.98	5.99	5.14	-1.11	-3.91	-5.94	-8.11	-6.65	-4.67	-3.82	-5.53	-6.36	-5.7	-4.1	-3.43	-3.84	-4.46	-4.87	-5.2	-5.27	-5.15	-5.62	-5.84	-6.39	-7.18	-7.14	-4.91	-1.06	1.22	-0.059	-3.53	-6.92	-12.6	-15.9	-15	-14.3	-13.6	-11.9	-11.6	-12.9	-13.7	-13.1	-10.3	-5.36	-1.23	0.88	0.9	1.96	3.51	4.55

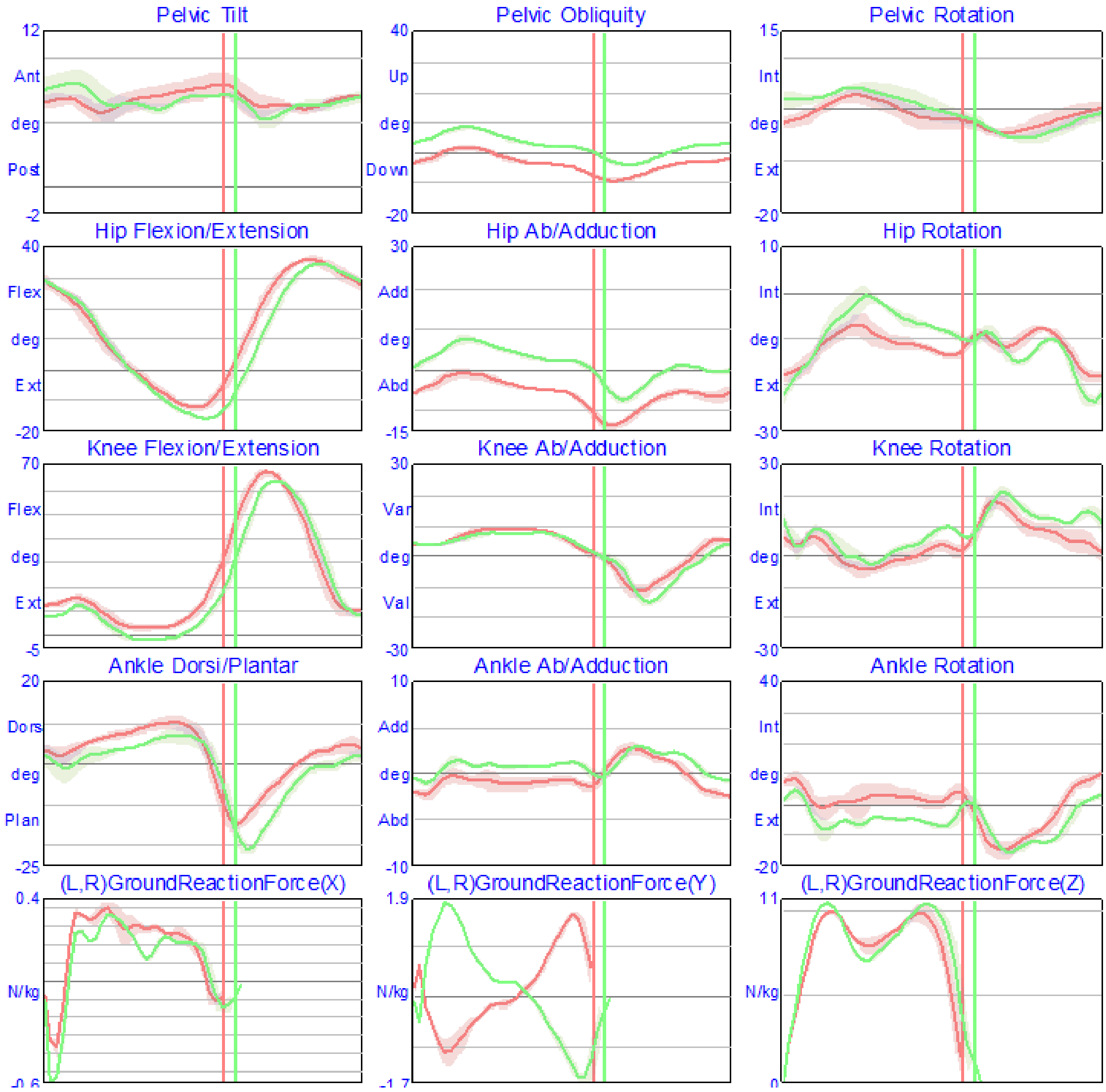
Kinetics	axis of movement	Force (N/kg)																													
LGroundReactionForce	x-axis	-0.082	-0.33	-0.29	-0.077	0.2	0.35	0.36	0.35	0.4	0.44	0.44	0.43	0.41	0.38	0.37	0.34	0.3	0.28	0.28	0.27	0.24	0.22	0.2	0.19	0.15	0.04	-0.1	-0.1	-0.032	
RGroundReactionForce	x-axis	-0.1	-0.55	-0.52	-0.26	0.088	0.27	0.27	0.22	0.24	0.32	0.37	0.35	0.32	0.28	0.23	0.16	0.12	0.16	0.23	0.25	0.22	0.21	0.21	0.21	0.2	0.12	-0.014	-0.13	-0.16	-0.086
LGroundReactionForce	y-axis	0.14	0.6	-0.15	-0.48	-0.69	-0.77	-0.72	-0.59	-0.46	-0.38	-0.35	-0.19	-0.088	-0.16	-0.23	-0.2	-0.039	0.15	0.29	0.4	0.56	0.78	1.01	1.26	1.47	1.61	1.48	0.93	0.3	
RGroundReactionForce	y-axis	-0.083	-0.46	0.68	1.37	1.64	1.89	1.8	1.56	1.24	0.96	0.73	0.55	0.4	0.3	0.29	0.3	0.29	0.17	0.037	-0.11	-0.32	-0.53	-0.74	-0.96	-1.22	-1.48	-1.66	-1.52	-0.92	-0.29
LGroundReactionForce	z-axis	0.4	2.62	4.27	6.11	7.59	8.92	9.88	10.4	10.4	10.1	9.41	8.74	8.28	8.06	8.13	8.41	8.8	9.07	9.43	9.97	10.4	10.6	10.6	10.2	9.45	7.93	5.64	2.97	1.22	
RGroundReactionForce	z-axis	0.36	2.79	4.66	7.26	8.74	10	10.7	10.9	10.6	9.86	8.94	8.08	7.55	7.47	7.69	8.09	8.5	8.85	9.17	9.67	10.3	10.7	10.8	10.8	10.4	9.66	8.28	6.05	3.42	1.49

4.3.1. Example of Polygon graph – single capture of subject XXX



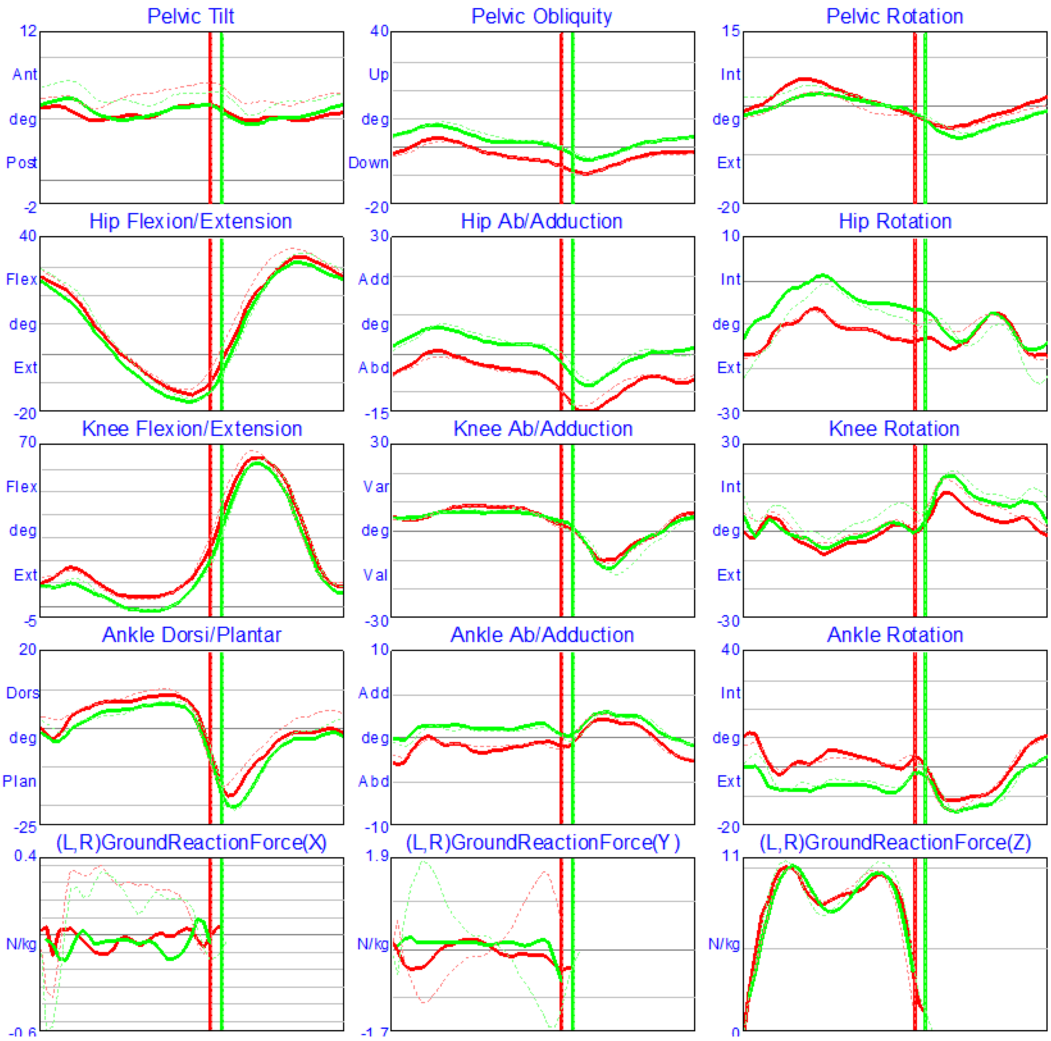
TEMPORAL PARAMETERS		
Cadence average both L.L.s	104 steps/min	
	Left	Right
Cadence	103 steps/min	104 steps/min
Limp Index	0.97	0.97
Step Length	0.67 m	0.63 m
Step Time	0.63 s	0.52 s
Step Width	0.083 m	0.11 m
Stride Length	1.29 m	1.30 m
Stride Time	1.17 s	1.15 s
Walking Speed	1.11 m/s	1.13 m/s

4.3.2. Example of Polygon graph –average of three captures



TEMPORAL PARAMETERS		
Cadence average both L.L.s	109 steps/min	
	Left	Right
Cadence	108 steps/min	108 steps/min
Limp Index	0.9	1.05
Step Length	0.67 m	0.65 m
Step Time	0.59 s	0.53 s
Step Width	0.093 m	0.12 m
Stride Length	1.29 m	1.31 m
Stride Time	1.11 s	1.11 s
Walking Speed	1.17 m/s	1.18 m/s

4.3.3. Example of Polygon graph – Pre- vs Post-averages



TEMPORAL PARAMETERS				
Instance in research	PRE		POST	
Cadence average both L.L.s	109 steps/min		106 steps/min	
	Left	Right	Left	Right
Cadence	108 steps/min	108 steps/min	101 steps/min	107 steps/min
Limp Index	0.9	1.05	0.94	1.08
Step Length	0.67 m	0.65 m	0.63 m	0.61 m
Step Time	0.59 s	0.53 s	0.58 s	0.56 s
Step Width	0.093 m	0.12 m	0.12 m	0.11 m
Stride Length	1.29 m	1.31 m	1.23 m	1.23 m
Stride Time	1.11 s	1.11 s	1.19 s	1.12 s
Walking Speed	1.17 m/s	1.18 m/s	1.03 m/s	1.09 m/s

Normative Data

This section is an integral step in the statistical processing of the gathered raw data. Establishing whether the data collected is normally and non-normally distributed dictates which statistical tests were to be applied to the data collected. The Kolmogorov-Smirnov (KS) and Shapiro-Wilk (SW) are the two main statistical tests which are used to verify the normality of a dataset. Their respective use is dependent on the specific characteristics of a dataset and the goals of its analysis (Reynolds & Kamphaus, 2015).

- **The Kolmogorov-Smirnov Test (KS)**: is a non-parametric test that compares the cumulative distribution function (CDF) of the sample data to the CDF of the normal distribution. It tests the null hypothesis that the sample comes from a normal distribution with a specified mean and variance (Kolmogorov, 1933). The KS test is sensitive to differences in both location and shape of the distributions, making it a more general test than the SW test (Creswell, 2014).
- **The Shapiro-Wilk Test (SW)**: is a parametric test that tests the null hypothesis that a sample comes from a normal distribution with an unknown mean and variance. It calculates a test statistic based on the sample data and compares it to the expected distribution of the test statistic under the null hypothesis (Shapiro & Wilk, 1965). The SW test is generally more powerful than the KS test when testing for normality, but it is sensitive to deviations from normality in the tails of the distribution. The Shapiro–Wilk test is more appropriate method for small sample sizes (<50 samples) (Creswell, 2014).

Table 4.3.1: Distribution of data for all investigated parameters: Tests of Normality			
	Shapiro-Wilk		
	Statistic	df	Sig.
Heart Rate Rest	0.912	8	0.370
Heart Rate End	0.934	8	0.552
Change in Heart Rate	0.966	8	0.867
Heart Rate Maximum	0.921	8	0.442
Distance	0.976	8	0.941
Maximum Speed	0.906	8	0.324
Cadence Pre	0.991	8	0.996
Cadence Post	0.868	8	0.143
Limp Index Left Pre	0.950	8	0.715
Limp Index Right Pre	0.905	8	0.318
Limp Index Left Post	0.776	8	0.056
Limp Index Right Post	0.913	8	0.375
Step Length Left Pre	0.971	8	0.907
Step Length Right Pre	0.970	8	0.899
Step Length Left Post	0.945	8	0.663
Step Length Right Post	0.902	8	0.303
Step Time Left Pre	0.927	8	0.487
Step Time Right Pre	0.963	8	0.838
Step Time Left Post	0.961	8	0.821
Step Time Right Post	0.925	8	0.476
Step Width Left Pre	0.954	8	0.756
Step Width Right Pre	0.976	8	0.938
Step Width Left Post	0.920	8	0.432
Step Width Right Post	0.955	8	0.762
Walking Speed Left Pre	0.962	8	0.832
Walking Speed Right Pre	0.938	8	0.588
Walking Speed Left Post	0.845	8	0.085
Walking Speed Right Post	0.908	8	0.339
Stride Time Left Pre	0.983	8	0.976
Stride Time Right Pre	0.928	8	0.496
Stride Time Left Post	0.929	8	0.503
Stride Time Right Post	0.856	8	0.109
Stride Length Left Pre	0.990	8	0.995
Stride Length Right Pre	0.968	8	0.878
Stride Length Left Post	0.953	8	0.739
Stride Length Right Post	0.931	8	0.527
Change in Cadence	0.966	8	0.869
Change in Limp Index Left	0.949	8	0.705

Change in Limp Index Right	0.962	8	0.829
Change in Step Length Left	0.931	8	0.524
Change in Step Length Right	0.900	8	0.289
Change in Step Time Left	0.924	8	0.461
Change in Step Time Right	0.939	8	0.603
Change in Step Width Left	0.849	8	0.093
Change in Step Width Right	0.793	8	0.074
Change in Walking Speed Left	0.890	8	0.234
Change in Walking Speed Right	0.826	8	0.064
Change in Stride Time Left	0.902	8	0.303
Change in Stride Time Right	0.903	8	0.306
Change in Stride Length Left	0.959	8	0.803
Change in Stride Length Right	0.963	8	0.834
SPO_2 RPE 6	0.702	8	0.082
SPO_2 RPE 7	0.905	8	0.319
SPO_2 RPE 8	0.876	8	0.173
SPO_2 RPE 9	0.798	8	0.097
SPO_2 RPE 10	0.905	8	0.319
SPO_2 RPE 11	0.607	8	0.090
SPO_2 RPE 12	0.850	8	0.095
SPO_2 RPE 13	0.800	8	0.069
SPO_2 RPE 14	0.671	8	0.081
SPO_2 RPE 15	0.861	8	0.123
SPO_2 RPE 16	0.602	8	0.045
SPO_2 RPE 17	0.418	8	0.063
SPO_2 RPE 18	0.877	8	0.178
SPO_2 RPE 19	0.847	8	0.088
SPO_2 RPE 20	0.815	8	0.071
HR RPE 6	0.879	8	0.185
HR RPE 7	0.933	8	0.547
HR RPE 8	0.883	8	0.202
HR RPE 9	0.835	8	0.066
HR RPE 10	0.912	8	0.372
HR RPE 11	0.628	8	0.082
HR RPE 12	0.728	8	0.055
HR RPE 13	0.740	8	0.076
HR RPE 14	0.874	8	0.165
HR RPE 15	0.561	8	0.084
HR RPE 16	0.952	8	0.729
HR RPE 17	0.888	8	0.222
HR RPE 18	0.815	8	0.092
HR RPE 19	0.888	8	0.225
HR RPE 20	0.804	8	0.062

Speed RPE 6	1.000	8	1.000
Speed RPE 7	0.931	8	0.529
Speed RPE 8	0.802	8	0.090
Speed RPE 9	0.799	8	0.068
Speed RPE 10	0.908	8	0.341
Speed RPE 11	0.957	8	0.777
Speed RPE 12	0.803	8	0.091
Speed RPE 13	0.927	8	0.485
Speed RPE 14	0.851	8	0.098
Speed RPE 15	0.821	8	0.098
Speed RPE 16	0.806	8	0.093
Speed RPE 17	0.821	8	0.048
Speed RPE 18	0.775	8	0.075
Speed RPE 19	0.861	8	0.123
Speed RPE 20	0.923	8	0.453
Heel Strike Pelvic Tilt (Left)Pre	0.899	8	0.285
Heel Strike Pelvic Tilt (Left)Post	0.985	8	0.983
Heel Strike Pelvic Tilt (Right)Pre	0.952	8	0.733
Heel Strike Pelvic Tilt (Right)Post	0.967	8	0.874
Heel Strike Hip Flexion/Extension (Left)Pre	0.944	8	0.650
Heel Strike Hip Flexion/Extension (Left)Post	0.962	8	0.831
Heel Strike Hip Flexion/Extension (Right)Pre	0.913	8	0.374
Heel Strike Hip Flexion/Extension (Right)Post	0.969	8	0.892
Heel Strike Knee Flexion/Extension (Left)Pre	0.890	8	0.235
Heel Strike Knee Flexion/Extension (Left)Post	0.887	8	0.221
Heel Strike Knee Flexion/Extension (Right)Pre	0.970	8	0.896
Heel Strike Knee Flexion/Extension (Right)Post	0.926	8	0.480
Heel Strike Ankle Dorsi/Plantar Flexion (Left)Pre	0.910	8	0.355
Heel Strike Ankle Dorsi/Plantar Flexion (Left)Post	0.849	8	0.094
Heel Strike Ankle Dorsi/Plantar Flexion (Right)Pre	0.934	8	0.556
Heel Strike Ankle Dorsi/Plantar Flexion (Right)Post	0.932	8	0.537
Heel Strike GRF X-axis (Left)Pre	0.830	8	0.060
Heel Strike GRF X-axis (Left)Post	0.851	8	0.099
Heel Strike GRF X-axis (Right)Pre	0.868	8	0.143
Heel Strike GRF X-axis (Right)Post	0.936	8	0.576
Heel Strike Pelvic Obliquity (Left)Pre	0.907	8	0.336
Heel Strike Pelvic Obliquity (Left)Post	0.950	8	0.708
Heel Strike Pelvic Obliquity (Right)Pre	0.926	8	0.484
Heel Strike Pelvic Obliquity (Right)Post	0.962	8	0.825
Heel Strike Hip Ab/Adduction (Left)Pre	0.891	8	0.240
Heel Strike Hip Ab/Adduction (Left)Post	0.889	8	0.230
Heel Strike Hip Ab/Adduction (Right)Pre	0.865	8	0.133
Heel Strike Hip Ab/Adduction (Right)Post	0.892	8	0.245

Heel Strike Knee Ab/Adduction (Left)Pre	0.972	8	0.913
Heel Strike Knee Ab/Adduction (Left)Post	0.969	8	0.893
Heel Strike Knee Ab/Adduction (Right)Pre	0.947	8	0.680
Heel Strike Knee Ab/Adduction (Right)Post	0.952	8	0.730
Heel Strike Ankle Ab/Adduction (Left)Pre	0.916	8	0.397
Heel Strike Ankle Ab/Adduction (Left)Post	0.943	8	0.642
Heel Strike Ankle Ab/Adduction (Right)Pre	0.990	8	0.995
Heel Strike Ankle Ab/Adduction (Right)Post	0.942	8	0.626
Heel Strike GRF Y-axis (Left)Pre	0.890	8	0.235
Heel Strike GRF Y-axis (Left)Post	0.904	8	0.312
Heel Strike GRF Y-axis (Right)Pre	0.905	8	0.323
Heel Strike GRF Y-axis (Right)Post	0.917	8	0.404
Heel Strike Pelvic Rotation (Left)Pre	0.980	8	0.964
Heel Strike Pelvic Rotation (Left)Post	0.955	8	0.757
Heel Strike Pelvic Rotation (Right)Pre	0.934	8	0.554
Heel Strike Pelvic Rotation (Right)Post	0.763	8	0.081
Heel Strike Hip Rotation (Left)Pre	0.893	8	0.250
Heel Strike Hip Rotation (Left)Post	0.821	8	0.097
Heel Strike Hip Rotation (Right)Pre	0.949	8	0.706
Heel Strike Hip Rotation (Right)Post	0.883	8	0.203
Heel Strike Knee Rotation (Left)Pre	0.991	8	0.997
Heel Strike Knee Rotation (Left)Post	0.924	8	0.466
Heel Strike Knee Rotation (Right)Pre	0.829	8	0.058
Heel Strike Knee Rotation (Right)Post	0.829	8	0.059
Heel Strike Ankle Rotation (Left)Pre	0.876	8	0.171
Heel Strike Ankle Rotation (Left)Post	0.956	8	0.769
Heel Strike Ankle Rotation (Right)Pre	0.945	8	0.661
Heel Strike Ankle Rotation (Right)Post	0.925	8	0.471
Heel Strike GRF Z-axis (Left)Pre	0.950	8	0.716
Heel Strike GRF Z-axis (Left)Post	0.945	8	0.665
Heel Strike GRF Z-axis (Right)Pre	0.974	8	0.928
Heel Strike GRF Z-axis (Right)Post	0.918	8	0.416
Mid Stance Pelvic Tilt (Left)Pre	0.960	8	0.809
Mid Stance Pelvic Tilt (Left)Post	0.954	8	0.752
Mid Stance Pelvic Tilt (Right)Pre	0.911	8	0.359
Mid Stance Pelvic Tilt (Right)Post	0.938	8	0.590
Mid Stance Hip Flexion/Extension (Left)Pre	0.862	8	0.127
Mid Stance Hip Flexion/Extension (Left)Post	0.889	8	0.229
Mid Stance Hip Flexion/Extension (Right)Pre	0.939	8	0.602
Mid Stance Hip Flexion/Extension (Right)Post	0.776	8	0.076
Mid Stance Knee Flexion/Extension (Left)Pre	0.920	8	0.430
Mid Stance Knee Flexion/Extension (Left)Post	0.952	8	0.736
Mid Stance Knee Flexion/Extension (Right)Pre	0.972	8	0.913

Mid Stance Knee Flexion/Extension (Right)Post	0.936	8	0.571
Mid Stance Ankle Dorsi/Plantar Flexion (Left)Pre	0.964	8	0.845
Mid Stance Ankle Dorsi/Plantar Flexion (Left)Post	0.979	8	0.955
Mid Stance Ankle Dorsi/Plantar Flexion (Right)Pre	0.872	8	0.157
Mid Stance Ankle Dorsi/Plantar Flexion (Right)Post	0.868	8	0.145
Mid Stance GRF X-axis (Left)Pre	0.986	8	0.987
Mid Stance GRF X-axis (Left)Post	0.931	8	0.526
Mid Stance GRF X-axis (Right)Pre	0.906	8	0.330
Mid Stance GRF X-axis (Right)Post	0.923	8	0.458
Mid Stance Pelvic Obliquity (Left)Pre	0.948	8	0.694
Mid Stance Pelvic Obliquity (Left)Post	0.958	8	0.787
Mid Stance Pelvic Obliquity (Right)Pre	0.967	8	0.877
Mid Stance Pelvic Obliquity (Right)Post	0.929	8	0.506
Mid Stance Hip Ab/Adduction (Left)Pre	0.814	8	0.090
Mid Stance Hip Ab/Adduction (Left)Post	0.710	8	0.073
Mid Stance Hip Ab/Adduction (Right)Pre	0.828	8	0.057
Mid Stance Hip Ab/Adduction (Right)Post	0.884	8	0.205
Mid Stance Knee Ab/Adduction (Left)Pre	0.894	8	0.253
Mid Stance Knee Ab/Adduction (Left)Post	0.903	8	0.310
Mid Stance Knee Ab/Adduction (Right)Pre	0.913	8	0.378
Mid Stance Knee Ab/Adduction (Right)Post	0.986	8	0.987
Mid Stance Ankle Ab/Adduction (Left)Pre	0.969	8	0.887
Mid Stance Ankle Ab/Adduction (Left)Post	0.981	8	0.969
Mid Stance Ankle Ab/Adduction (Right)Pre	0.967	8	0.872
Mid Stance Ankle Ab/Adduction (Right)Post	0.979	8	0.958
Mid Stance GRF Y-axis (Left)Pre	0.841	8	0.076
Mid Stance GRF Y-axis (Left)Post	0.824	8	0.051
Mid Stance GRF Y-axis (Right)Pre	0.923	8	0.455
Mid Stance GRF Y-axis (Right)Post	0.902	8	0.301
Mid Stance Pelvic Rotation (Left)Pre	0.967	8	0.876
Mid Stance Pelvic Rotation (Left)Post	0.945	8	0.661
Mid Stance Pelvic Rotation (Right)Pre	0.983	8	0.978
Mid Stance Pelvic Rotation (Right)Post	0.886	8	0.213
Mid Stance Hip Rotation (Left)Pre	0.903	8	0.308
Mid Stance Hip Rotation (Left)Post	0.864	8	0.132
Mid Stance Hip Rotation (Right)Pre	0.915	8	0.393
Mid Stance Hip Rotation (Right)Post	0.922	8	0.450
Mid Stance Knee Rotation (Left)Pre	0.966	8	0.868
Mid Stance Knee Rotation (Left)Post	0.927	8	0.487
Mid Stance Knee Rotation (Right)Pre	0.784	8	0.099
Mid Stance Knee Rotation (Right)Post	0.776	8	0.056
Mid Stance Ankle Rotation (Left)Pre	0.916	8	0.397
Mid Stance Ankle Rotation (Left)Post	0.963	8	0.836

Mid Stance Ankle Rotation (Right)Pre	0.900	8	0.292
Mid Stance Ankle Rotation (Right)Post	0.967	8	0.874
Mid Stance GRF Z-axis (Left)Pre	0.970	8	0.896
Mid Stance GRF Z-axis (Left)Post	0.918	8	0.413
Mid Stance GRF Z-axis (Right)Pre	0.908	8	0.338
Mid Stance GRF Z-axis (Right)Post	0.876	8	0.173
Weight Transference Pelvic Tilt (Left)Pre	0.979	8	0.955
Weight Transference Pelvic Tilt (Left)Post	0.937	8	0.582
Weight Transference Pelvic Tilt (Right)Pre	0.928	8	0.495
Weight Transference Pelvic Tilt (Right)Post	0.957	8	0.784
Weight Transference Hip Flexion/Extension (Left)Pre	0.862	8	0.126
Weight Transference Hip Flexion/Extension (Left)Post	0.857	8	0.112
Weight Transference Hip Flexion/Extension (Right)Pre	0.907	8	0.334
Weight Transference Hip Flexion/Extension (Right)Post	0.715	8	0.073
Weight Transference Knee Flexion/Extension (Left)Pre	0.920	8	0.434
Weight Transference Knee Flexion/Extension (Left)Post	0.882	8	0.198
Weight Transference Knee Flexion/Extension (Right)Pre	0.898	8	0.274
Weight Transference Knee Flexion/Extension (Right)Post	0.942	8	0.626
Weight Transference Ankle Dorsi/Plantar Flexion (Left)Pre	0.997	8	1.000
Weight Transference Ankle Dorsi/Plantar Flexion (Left)Post	0.965	8	0.859
Weight Transference Ankle Dorsi/Plantar Flexion (Right)Pre	0.894	8	0.254
Weight Transference Ankle Dorsi/Plantar Flexion (Right)Post	0.919	8	0.420
Weight Transference GRF X-axis (Left)Pre	0.919	8	0.424
Weight Transference GRF X-axis (Left)Post	0.917	8	0.403
Weight Transference GRF X-axis (Right)Pre	0.925	8	0.474
Weight Transference GRF X-axis (Right)Post	0.940	8	0.612
Weight Transference Pelvic Obliquity (Left)Pre	0.965	8	0.860
Weight Transference Pelvic Obliquity (Left)Post	0.893	8	0.248
Weight Transference Pelvic Obliquity (Right)Pre	0.932	8	0.532
Weight Transference Pelvic Obliquity (Right)Post	0.952	8	0.728
Weight Transference Hip Ab/Adduction (Left)Pre	0.944	8	0.648
Weight Transference Hip Ab/Adduction (Left)Post	0.933	8	0.545
Weight Transference Hip Ab/Adduction (Right)Pre	0.864	8	0.131
Weight Transference Hip Ab/Adduction (Right)Post	0.901	8	0.297
Weight Transference Knee Ab/Adduction (Left)Pre	0.965	8	0.854
Weight Transference Knee Ab/Adduction (Left)Post	0.951	8	0.723
Weight Transference Knee Ab/Adduction (Right)Pre	0.925	8	0.469
Weight Transference Knee Ab/Adduction (Right)Post	0.935	8	0.560
Weight Transference Ankle Ab/Adduction (Left)Pre	0.960	8	0.809
Weight Transference Ankle Ab/Adduction (Left)Post	0.989	8	0.994
Weight Transference Ankle Ab/Adduction (Right)Pre	0.909	8	0.349
Weight Transference Ankle Ab/Adduction (Right)Post	0.906	8	0.329
Weight Transference GRF Y-axis (Left)Pre	0.895	8	0.261

Weight Transference GRF Y-axis (Left)Post	0.936	8	0.574
Weight Transference GRF Y-axis (Right)Pre	0.864	8	0.131
Weight Transference GRF Y-axis (Right)Post	0.870	8	0.151
Weight Transference Pelvic Rotation (Left)Pre	0.945	8	0.663
Weight Transference Pelvic Rotation (Left)Post	0.972	8	0.915
Weight Transference Pelvic Rotation (Right)Pre	0.984	8	0.979
Weight Transference Pelvic Rotation (Right)Post	0.840	8	0.075
Weight Transference Hip Rotation (Left)Pre	0.937	8	0.585
Weight Transference Hip Rotation (Left)Post	0.882	8	0.196
Weight Transference Hip Rotation (Right)Pre	0.934	8	0.553
Weight Transference Hip Rotation (Right)Post	0.920	8	0.431
Weight Transference Knee Rotation (Left)Pre	0.967	8	0.872
Weight Transference Knee Rotation (Left)Post	0.923	8	0.455
Weight Transference Knee Rotation (Right)Pre	0.858	8	0.115
Weight Transference Knee Rotation (Right)Post	0.799	8	0.078
Weight Transference Ankle Rotation (Left)Pre	0.977	8	0.949
Weight Transference Ankle Rotation (Left)Post	0.929	8	0.507
Weight Transference Ankle Rotation (Right)Pre	0.894	8	0.256
Weight Transference Ankle Rotation (Right)Post	0.907	8	0.332
Weight Transference GRF Z-axis (Left)Pre	0.903	8	0.307
Weight Transference GRF Z-axis (Left)Post	0.960	8	0.812
Weight Transference GRF Z-axis (Right)Pre	0.927	8	0.486
Weight Transference GRF Z-axis (Right)Post	0.940	8	0.613
Toe off Pelvic Tilt (Left)Pre	0.961	8	0.822
Toe off Pelvic Tilt (Left)Post	0.958	8	0.795
Toe off Pelvic Tilt (Right)Pre	0.950	8	0.716
Toe off Pelvic Tilt (Right)Post	0.972	8	0.915
Toe off Hip Flexion/Extension (Left)Pre	0.888	8	0.226
Toe off Hip Flexion/Extension (Left)Post	0.891	8	0.238
Toe off Hip Flexion/Extension (Right)Pre	0.936	8	0.568
Toe off Hip Flexion/Extension (Right)Post	0.935	8	0.559
Toe off Knee Flexion/Extension (Left)Pre	0.927	8	0.485
Toe off Knee Flexion/Extension (Left)Post	0.961	8	0.817
Toe off Knee Flexion/Extension (Right)Pre	0.802	8	0.080
Toe off Knee Flexion/Extension (Right)Post	0.924	8	0.459
Toe off Ankle Dorsi/Plantar Flexion (Left)Pre	0.911	8	0.362
Toe off Ankle Dorsi/Plantar Flexion (Left)Post	0.983	8	0.975
Toe off Ankle Dorsi/Plantar Flexion (Right)Pre	0.877	8	0.175
Toe off Ankle Dorsi/Plantar Flexion (Right)Post	0.892	8	0.243
Toe off GRF X-axis (Left)Pre	1.000	8	1.000
Toe off GRF X-axis (Left)Post	1.000	8	1.000
Toe off GRF X-axis (Right)Pre	1.000	8	1.000
Toe off GRF X-axis (Right)Post	1.000	8	1.000

Toe off Pelvic Obliquity (Left)Pre	0.908	8	0.342
Toe off Pelvic Obliquity (Left)Post	0.910	8	0.353
Toe off Pelvic Obliquity (Right)Pre	0.908	8	0.338
Toe off Pelvic Obliquity (Right)Post	0.947	8	0.680
Toe off Hip Ab/Adduction (Left)Pre	0.980	8	0.963
Toe off Hip Ab/Adduction (Left)Post	0.933	8	0.541
Toe off Hip Ab/Adduction (Right)Pre	0.912	8	0.367
Toe off Hip Ab/Adduction (Right)Post	0.965	8	0.859
Toe off Knee Ab/Adduction (Left)Pre	0.959	8	0.799
Toe off Knee Ab/Adduction (Left)Post	0.897	8	0.271
Toe off Knee Ab/Adduction (Right)Pre	0.933	8	0.544
Toe off Knee Ab/Adduction (Right)Post	0.936	8	0.574
Toe off Ankle Ab/Adduction (Left)Pre	0.951	8	0.719
Toe off Ankle Ab/Adduction (Left)Post	0.817	8	0.093
Toe off Ankle Ab/Adduction (Right)Pre	0.825	8	0.053
Toe off Ankle Ab/Adduction (Right)Post	0.813	8	0.040
Toe off GRF Y-axis (Left)Pre	1.000	8	1.000
Toe off GRF Y-axis (Left)Post	1.000	8	1.000
Toe off GRF Y-axis (Right)Pre	1.000	8	1.000
Toe off GRF Y-axis (Right)Post	1.000	8	1.000
Toe off Pelvic Rotation (Left)Pre	0.891	8	0.241
Toe off Pelvic Rotation (Left)Post	0.962	8	0.831
Toe off Pelvic Rotation (Right)Pre	0.956	8	0.770
Toe off Pelvic Rotation (Right)Post	0.933	8	0.546
Toe off Hip Rotation (Left)Pre	0.975	8	0.936
Toe off Hip Rotation (Left)Post	0.938	8	0.589
Toe off Hip Rotation (Right)Pre	0.901	8	0.293
Toe off Hip Rotation (Right)Post	0.949	8	0.701
Toe off Knee Rotation (Left)Pre	0.932	8	0.537
Toe off Knee Rotation (Left)Post	0.889	8	0.230
Toe off Knee Rotation (Right)Pre	0.838	8	0.071
Toe off Knee Rotation (Right)Post	0.835	8	0.067
Toe off Ankle Rotation (Left)Pre	0.963	8	0.836
Toe off Ankle Rotation (Left)Post	0.769	8	0.013
Toe off Ankle Rotation (Right)Pre	0.880	8	0.187
Toe off Ankle Rotation (Right)Post	0.898	8	0.278
Toe off GRF Z-axis (Left)Pre	1.000	8	1.000
Toe off GRF Z-axis (Left)Post	1.000	8	1.000
Toe off GRF Z-axis (Right)Pre	1.000	8	1.000
Toe off GRF Z-axis (Right)Post	1.000	8	1.000
Mid Swing Pelvic Tilt (Left)Pre	0.926	8	0.485
Mid Swing Pelvic Tilt (Left)Post	0.925	8	0.474
Mid Swing Pelvic Tilt (Right)Pre	0.964	8	0.849

Mid Swing Pelvic Tilt (Right)Post	0.939	8	0.604
Mid Swing Hip Flexion/Extension (Left)Pre	0.929	8	0.503
Mid Swing Hip Flexion/Extension (Left)Post	0.923	8	0.453
Mid Swing Hip Flexion/Extension (Right)Pre	0.901	8	0.293
Mid Swing Hip Flexion/Extension (Right)Post	0.865	8	0.134
Mid Swing Knee Flexion/Extension (Left)Pre	0.875	8	0.170
Mid Swing Knee Flexion/Extension (Left)Post	0.796	8	0.026
Mid Swing Knee Flexion/Extension (Right)Pre	0.918	8	0.414
Mid Swing Knee Flexion/Extension (Right)Post	0.772	8	0.064
Mid Swing Ankle Dorsi/Plantar Flexion (Left)Pre	0.884	8	0.207
Mid Swing Ankle Dorsi/Plantar Flexion (Left)Post	0.973	8	0.921
Mid Swing Ankle Dorsi/Plantar Flexion (Right)Pre	0.907	8	0.335
Mid Swing Ankle Dorsi/Plantar Flexion (Right)Post	0.942	8	0.631
Mid Swing GRF X-axis (Left)Pre	1.000	8	1.000
Mid Swing GRF X-axis (Left)Post	1.000	8	1.000
Mid Swing GRF X-axis (Right)Pre	1.000	8	1.000
Mid Swing GRF X-axis (Right)Post	1.000	8	1.000
Mid Swing Pelvic Obliquity (Left)Pre	0.807	8	0.074
Mid Swing Pelvic Obliquity (Left)Post	0.884	8	0.206
Mid Swing Pelvic Obliquity (Right)Pre	0.916	8	0.395
Mid Swing Pelvic Obliquity (Right)Post	0.980	8	0.964
Mid Swing Hip Ab/Adduction (Left)Pre	0.965	8	0.854
Mid Swing Hip Ab/Adduction (Left)Post	0.964	8	0.850
Mid Swing Hip Ab/Adduction (Right)Pre	0.959	8	0.799
Mid Swing Hip Ab/Adduction (Right)Post	0.950	8	0.713
Mid Swing Knee Ab/Adduction (Left)Pre	0.914	8	0.386
Mid Swing Knee Ab/Adduction (Left)Post	0.920	8	0.430
Mid Swing Knee Ab/Adduction (Right)Pre	0.888	8	0.225
Mid Swing Knee Ab/Adduction (Right)Post	0.959	8	0.804
Mid Swing Ankle Ab/Adduction (Left)Pre	0.840	8	0.075
Mid Swing Ankle Ab/Adduction (Left)Post	0.887	8	0.219
Mid Swing Ankle Ab/Adduction (Right)Pre	0.939	8	0.602
Mid Swing Ankle Ab/Adduction (Right)Post	0.910	8	0.355
Mid Swing GRF Y-axis (Left)Pre	1.000	8	1.000
Mid Swing GRF Y-axis (Left)Post	1.000	8	1.000
Mid Swing GRF Y-axis (Right)Pre	1.000	8	1.000
Mid Swing GRF Y-axis (Right)Post	1.000	8	1.000
Mid Swing Pelvic Rotation (Left)Pre	0.983	8	0.977
Mid Swing Pelvic Rotation (Left)Post	0.797	8	0.087
Mid Swing Pelvic Rotation (Right)Pre	0.947	8	0.676
Mid Swing Pelvic Rotation (Right)Post	0.804	8	0.092
Mid Swing Hip Rotation (Left)Pre	0.873	8	0.160
Mid Swing Hip Rotation (Left)Post	0.901	8	0.293

Mid Swing Hip Rotation (Right)Pre	0.903	8	0.308
Mid Swing Hip Rotation (Right)Post	0.837	8	0.071
Mid Swing Knee Rotation (Left)Pre	0.969	8	0.892
Mid Swing Knee Rotation (Left)Post	0.974	8	0.927
Mid Swing Knee Rotation (Right)Pre	0.965	8	0.853
Mid Swing Knee Rotation (Right)Post	0.962	8	0.831
Mid Swing Ankle Rotation (Left)Pre	0.836	8	0.068
Mid Swing Ankle Rotation (Left)Post	0.844	8	0.082
Mid Swing Ankle Rotation (Right)Pre	0.897	8	0.274
Mid Swing Ankle Rotation (Right)Post	0.873	8	0.162
Mid Swing GRF Z-axis (Left)Pre	1.000	8	1.000
Mid Swing GRF Z-axis (Left)Post	1.000	8	1.000
Mid Swing GRF Z-axis (Right)Pre	1.000	8	1.000
Mid Swing GRF Z-axis (Right)Post	1.000	8	1.000

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

4.4. Section A: Vicon Data

4.4.1. Captures Pre vs Captures Post

The Paired Samples T-test was used to compare mean pre-scores with mean post-scores. The null hypothesis specifies that the mean scores vary marginally between the two sessions and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean scores vary significantly between the two sessions and is accepted if the p-value is smaller than the 0.05 criterion.

The tables within this section (Section A) were divided into the five main stages of the gait cycle: Heel strike, Mid-stance, Weight Transference, Toe-off, and Mid-Swing. Each of these stipulated sections contained three tables which demonstrated a Paired Samples T-test comparing the mean pre- and post- kinematic and kinetic readings of:

- all the participants (**Table 4.4.1**; **4.4.4**; **4.4.7**; **4.4.10**; **4.4.13**),
- active participants (**Table 4.4.2**; **4.4.5**; **4.4.8**; **4.4.11**; **4.4.14**),
- sedentary participants (**Table 4.4.3**; **4.4.6**; **4.4.9**; **4.4.12**; **4.4.15**).

4.4.2. Heel-strike

A Paired Samples T-test was used to compare the mean pre-scores with mean post-scores during Heel strike. Significant changes ($p < 0.05$) in the movements captured included:

- **All participants**: GRF along the Z-axis both left and right lower limb,
- **Active participants**: GRF along the Z-axis both left and right lower limb,
- **Sedentary Participants**: Knee flexion and extension; Pelvic obliquity; and Ankle ab/adduction in the left lower limb.

No further significant changes were noted within this instance of gait.

Table 4.4.1: Statistical testing of significant mean pre- and post- kinetic statistical test results at Heel Strike from all participants (Paired Samples T test)

		Mean	N	S.D.	P value
GRF Z-axis (Left) (N)	Pre	9.584	40	0.92284	<0.001
	Post	10.074	40	0.83303	
GRF Z-axis (Right) (N)	Pre	9.841	40	1.07429	0.003
	Post	10.242	40	0.86536	

All the results are represented in Appendix 2 Table 2.1.

Table 4.4.2: Comparison of significant active participants' mean pre- and post- kinetic statistical test results at Heel Strike (Paired Samples T test)

		Mean	N	S.D.	P value
GRF Z-axis (Left) (N)	Pre	9.687	31	0.819	<0.001
	Post	10.169	31	0.769	
GRF Z-axis (Right) (N)	Pre	9.860	31	0.918	<0.001
	Post	10.241	31	0.778	

All the results are represented in Appendix 2 Table 2.2.

Table 4.4.3: Comparison of significant sedentary participants' mean pre- and post- kinematic statistical test results at Heel Strike (Paired Samples T test)

		Mean	N	S.D.	P value
Knee Flexion/Extension (Left) (degrees)	Pre	8.653	9	7.484	0.027
	Post	11.350	9	8.319	
Pelvic Obliquity (Left) (degrees)	Pre	2.036	9	2.878	0.036
	Post	2.960	9	2.895	
Ankle Ab/Adduction (Left) (degrees)	Pre	1.868	9	2.886	0.016
	Post	2.613	9	2.448	

All the results are represented in Appendix 2 Table 2.3.

4.4.3. Mid-Stance

A Paired Samples T-test was used to compare the mean pre-scores with mean post-scores during Mid-Stance. Significant changes ($p < 0.05$) in the movements captured included:

- **All participants**: GRF along the Z-axis in the left lower limb,
- **Active participants**: Knee Rotation; and GRF along the Z-axis in the left lower limb,
- **Sedentary Participants**: Knee flexion and extension; Ankle dorsi/plantarflexion; Hip ab/adduction; and ankle rotation in the left lower limb; Knee ab/adduction in the right lower limb.

No further significant changes were noted within this instance of gait.

Table 4.4.4: Comparison of all significant mean pre- and post- kinetic statistical test results at Mid-stance (Paired Samples T test)

		Mean	N	S.D.	P value
GRF Z-axis (Left) (N)	Pre	7.646	40	0.817	0.006
	Post	7.376	40	0.687	

All the results are represented in Appendix 2 Table 2.4.

Table 4.4.5: Comparison of significant active participants' mean pre- and post- kinematic and kinetic statistical test results at Mid-Stance (Paired Samples T test)

		Mean	N	S.D	P value
Knee Rotation (Left) (degrees)	Pre	2.478	31	8.790	0.040
	Post	0.603	31	10.499	
GRF Z-axis (Left) (N)	Pre	7.714	31	0.829	0.011
	Post	7.416	31	0.686	

All the results are represented in Appendix 2 Table 2.5.

Table 4.4.6: Comparison of significant sedentary participants' mean pre- and post- kinematic statistical test results at Mid-Stance (Paired Samples T test)

		Mean	N	S.D.	P value
Knee Flexion/Extension (Left) (degrees)	Pre	1.521	9	8.332	0.016
	Post	4.869	9	7.641	
Ankle Dorsi/Plantar Flexion (Left) (degrees)	Pre	4.683	9	15.710	0.043
	Post	5.810	9	15.011	
Hip Ab/Adduction (Left) (degrees)	Pre	1.067	9	3.253	0.041
	Post	1.937	9	3.561	
Knee Ab/Adduction (Right) (degrees)	Pre	3.440	9	4.464	0.050
	Post	2.813	9	3.952	
Ankle Rotation (Left) (degrees)	Pre	-5.418	9	11.001	0.029
	Post	-8.537	9	8.593	

All the results are represented in Appendix 2 Table 2.6.

4.4.4. Weight-transference

A Paired Samples T-test was used to compare the mean pre-scores with mean post-scores during Weight-Transference. Significant changes ($p < 0.05$) in the movements captured included:

- **All participants**: Pelvic Obliquity and Pelvic Rotation in the left lower limb; Ankle Dorsi/Plantarflexion; and Hip Rotation in the right lower limb,
- **Active participants**: Hip Ab/Adduction; Ankle Ab/Adduction; Pelvic Rotation; and Ankle Rotation in the left lower limb

  Ankle Dorsi/Plantarflexion; and Hip Rotation in the right lower limb,
- **Sedentary Participants**: Pelvic Obliquity; and Hip Rotation in the left lower limb; Ankle Dorsi/Plantarflexion in the right lower limb

No further significant changes were noted within this instance of gait.

Table 4.4.7: Comparison of all significant mean pre- and post- kinematic statistical test results at Weight-Transference (Paired Samples T test)

		Mean	N	S.D.	P value
Ankle Dorsi/Plantar Flexion (Right) (degrees)	Pre	14.463	40	9.888	0.002
	Post	13.547	40	9.990	
Pelvic Obliquity (Left) (degrees)	Pre	-0.582	40	2.402	0.020
	Post	-0.994	40	2.071	

Pelvic Rotation (Left) (degrees)	Pre	-2.851	40	5.034	0.047
	Post	-4.011	40	3.459	
Hip Rotation (Right) (degrees)	Pre	3.301	40	7.619	0.025
	Post	1.808	40	8.825	

All the results are represented in Appendix 2 Table 2.7.

Table 4.4.8: Comparison of significant active participants' mean pre- and post- kinematic statistical test results at Weight-Transference (Paired Samples T test)

		Mean	N	S.D.	P value
Ankle Dorsi/Plantar Flexion (Right) (degrees)	Pre	15.25	31	4.654	0.014
	Post	14.37	31	4.906	
Hip Ab/Adduction (Left) (degrees)	Pre	2.51	31	9.489	0.031
	Post	1.85	31	9.256	
Ankle Ab/Adduction (Left) (degrees)	Pre	1.82	31	2.628	0.039
	Post	1.44	31	3.013	
Pelvic Rotation (Left) (degrees)	Pre	-2.56	31	4.672	0.037
	Post	-3.91	31	3.705	
Hip Rotation (Right) (degrees)	Pre	3.00	31	7.254	0.021
	Post	1.06	31	8.566	
Ankle Rotation (Left) (degrees)	Pre	-7.19	31	9.184	0.038
	Post	-5.80	31	10.342	

All the results are represented in Appendix 2 Table 2.8.

Table 4.4.9: Comparison of significant sedentary participants' mean pre- and post- kinematic statistical test results at Weight-Transference (Paired Samples T test)

		Mean	N	S.D.	P value
Ankle Dorsi/Plantar Flexion (Right) (degrees)	Pre	11.767	9	19.618	0.050
	Post	10.724	9	19.614	
Pelvic Obliquity (Left) (degrees)	Pre	-0.990	9	3.370	0.034
	Post	-1.619	9	2.713	
Hip Rotation (Left) (degrees)	Pre	4.080	9	8.872	0.048
	Post	2.507	9	8.777	

All the results are represented in Appendix 2 Table 2.9.

4.4.5. Toe-off

A Paired Samples T-test was used to compare the mean pre-scores with mean post-scores during Toe-off. Significant changes ($p < 0.05$) in the movements captured included:

- **All participants**: Ankle Dorsi/Plantarflexion; Pelvic Obliquity and Hip Ab/Adduction in the left lower limb; Hip Rotation in the right lower limb,
- **Active participants**: Ankle Dorsi/Plantarflexion; Pelvic Obliquity; Hip Ab/Adduction; and Ankle Rotation in the left lower limb; Hip Ab/Adduction; and Hip Rotation in the right lower limb,
- **Sedentary Participants**: Pelvic Obliquity; and Hip Ab/Adduction in the left lower limb.

No further significant changes were noted within this instance of gait.

Table 4.4.10: Comparison of all significant mean pre- and post- kinematic statistical test results at Toe-Off (Paired Samples T test)

		Mean	N	S.D.	P value
Ankle Dorsi/Plantar Flexion (Left) (degrees)	Pre	-6.907	40	8.729	0.003
	Post	-10.721	40	10.225	
Pelvic Obliquity (Left) (degrees)	Pre	-2.995	40	2.836	<0.001
	Post	-3.945	40	2.646	
Hip Ab/Adduction (Left) (degrees)	Pre	-5.393	40	9.286	<0.001
	Post	-7.063	40	9.102	
Hip Rotation (Right) (degrees)	Pre	1.057	40	9.429	0.028
	Post	-0.840	40	10.068	

All the results are represented in Appendix 2 Table 2.10.

Table 4.4.11: Comparison of significant active participants' mean pre- and post- kinematic statistical test results at Toe-Off (Paired Samples T test)

		Mean	N	S.D.	P value
Ankle Dorsi/Plantar Flexion (Left) (degrees)	Pre	-8.137	31	6.418	0.012
	Post	-11.600	31	7.712	
Pelvic Obliquity (Left) (degrees)	Pre	-2.853	31	2.817	0.004
	Post	-3.636	31	2.541	
Hip Ab/Adduction (Left) (degrees)	Pre	-5.525	31	10.195	0.002
	Post	-7.023	31	10.054	
Hip Ab/Adduction (Right) (degrees)	Pre	-5.755	31	10.227	0.043
	Post	-6.674	31	10.410	
Hip Rotation (Right) (degrees)	Pre	1.205	31	8.686	0.024
	Post	-1.218	31	9.261	

Ankle Rotation (Left) (degrees)	Pre	-6.445	31	10.302	0.043
	Post	-5.063	31	11.282	

All the results are represented in Appendix 2 Table 2.11.

Table 4.4.12: Comparison of significant sedentary mean pre- and post- kinematic statistical test results at Toe-Off (Paired Samples T test)

		Mean	N	S.D.	P value
Pelvic Obliquity (Left) (degrees)	Pre	-3.486	9	3.017	0.017
	Post	-5.009	9	2.874	
Hip Ab/Adduction (Left) (degrees)	Pre	-4.939	9	5.504	0.027
	Post	-7.202	9	4.981	

All the results are represented in Appendix 2 Table 2.12.

4.4.6. Mid-Swing

A Paired Samples T-test was used to compare the mean pre-scores with mean post-scores during Mid-Swing. Significant changes ($p < 0.05$) in the movements captured included:

- **All participants**: Hip Flexion/Extension; Ankle Dorsi/Plantar Flexion; Hip Ab/Adduction; Knee Ab/Adduction and Knee Rotation in the left lower limb; Ankle Dorsi/Plantar Flexion; Hip Ab/Adduction; and Knee Ab/Adduction in the right lower limb,
- **Active participants**: Hip Flexion/Extension; Hip Ab/Adduction; Knee Ab/Adduction; and Knee Rotation in the left lower limb; Ankle Dorsi/Plantarflexion; Knee Ab/Adduction; and Pelvic Rotation in the right lower limb,
- **Sedentary Participants**: Pelvic Tilt in the left lower limb; Pelvic Obliquity; and Hip Ab/Adduction in the right lower limb.

No further significant changes were noted within this instance of gait.

Table 4.4.13: Comparison of all significant mean pre- and post- kinematic statistical test results at Mid-Swing (Paired Samples T test)

		Mean	N	S.D.	P value
Hip Flexion/Extension (Left) (degrees)	Pre	27.241	40	7.841	0.038
	Post	28.409	40	7.269	
Ankle Dorsi/Plantar Flexion (Left) (degrees)	Pre	1.880	40	9.031	0.017
	Post	0.351	40	7.986	

Ankle Dorsi/Plantar Flexion (Right) (degrees)	Pre	2.011	40	11.126	0.022
	Post	0.546	40	9.745	
Hip Ab/Adduction (Left) (degrees)	Pre	-2.561	40	9.317	0.008
	Post	-3.356	40	9.141	
Hip Ab/Adduction (Right) (degrees)	Pre	-2.378	40	9.372	0.021
	Post	-3.042	40	9.036	
Knee Ab/Adduction (Left) (degrees)	Pre	2.404	40	10.118	0.001
	Post	3.697	40	10.146	
Knee Ab/Adduction (Right) (degrees)	Pre	1.815	40	10.295	0.001
	Post	3.783	40	11.116	
Knee Rotation (Left) (degrees)	Pre	6.171	40	12.229	0.039
	Post	4.817	40	12.134	

All the results are represented in Appendix 2 Table 2.13.

Table 4.4.14: Comparison of significant active participants' mean pre- and post-kinematic statistical test results at Mid-Swing (Paired Samples T test)

		Mean	N	S.D.	P value
Hip Flexion/Extension (Left) (degrees)	Pre	28.152	31	6.940	0.010
	Post	29.584	31	6.306	
Ankle Dorsi/Plantar Flexion (Right) (degrees)	Pre	3.165	31	4.281	0.043
	Post	1.808	31	2.872	
Hip Ab/Adduction (Left) (degrees)	Pre	-2.101	31	10.244	0.021
	Post	-2.725	31	10.011	
Knee Ab/Adduction (Left) (degrees)	Pre	2.781	31	11.075	0.002
	Post	4.146	31	10.909	
Knee Ab/Adduction (Right) (degrees)	Pre	1.903	31	10.992	0.003
	Post	3.862	31	11.582	
Pelvic Rotation (Right) (degrees)	Pre	-1.407	31	4.524	0.032
	Post	-0.065	31	4.132	
Knee Rotation (Left) (degrees)	Pre	6.053	31	12.800	0.004
	Post	4.158	31	12.831	

All the results are represented in Appendix 2 Table 2.14.

Table 4.4.15: Comparison of significant sedentary mean pre- and post- kinematic statistical test results at Mid-Swing (Paired Samples T test)

		Mean	N	S.D.	P value
Pelvic Tilt (Left) (degrees)	Pre	6.433	9	8.401	0.047
	Post	5.150	9	8.197	
Pelvic Obliquity (Right) (degrees)	Pre	1.024	9	2.528	0.034
	Post	0.137	9	2.976	
Hip Ab/Adduction (Right)	Pre	-1.613	9	4.481	0.005

(degrees)	Post	-3.047	9	4.961	

All the results are represented in Appendix 2 Table 2.15.

4.4.7. Summary of Section A: Vicon Data

Table 4.4.16: Table summarizing significant differences

Type of data	*Instance observed*	*Participant population*	*Results Table*	*Observation – significant differences found*
Captures Pre vs Captures Post	*Heel-strike*	*All participants*	*Table 4.4.1*	*GRF along the Z-axis both left and right lower limb*
		Active Participants	*Table 4.4.2*	*GRF along the Z-axis both left and right lower limb*
		Sedentary Participants	*Table 4.4.3*	*Knee flexion and extension; Pelvic obliquity; and Ankle ab/adduction in the left lower limb.*
	Mid-Stance	*All participants*	*Table 4.4.4*	*GRF along the Z-axis in the left lower limb,*
		Active Participants	*Table 4.4.5*	*Knee Rotation; and GRF along the Z-axis in the left lower limb,*
		Sedentary Participants	*Table 4.4.6*	*Knee flexion and extension; Ankle dorsi/plantarflexion; Hip ab/adduction; and ankle rotation in the left lower limb; Knee ab/adduction in the right lower limb.*
	Weight-transference	*All participants*	*Table 4.4.7*	*Pelvic Obliquity and Pelvic Rotation in the left lower limb; Ankle dorsi/plantarflexion; and Hip rotation in the right lower limb*
		Active Participants	*Table 4.4.8*	*Hip ab/adduction; ankle ab/adduction; pelvic rotation; and ankle rotation in the left lower limb, Ankle dorsi/plantarflexion; GRF along the X-axis; and Hip rotation in the right lower limb*

		Sedentary Participants	*Table 4.4.9*	*Pelvic obliquity; and Hip rotation in the left lower limb; Ankle dorsi/plantarflexion in the right lower limb*
	Toe-off	*All participants*	*Table 4.4.10*	*Ankle dorsi/plantarflexion; Pelvic Obliquity and Hip ab/adduction in the left lower limb; Hip rotation in the right lower limb*
		Active Participants	*Table 4.4.11*	*Ankle dorsi/plantarflexion; Pelvic Obliquity; Hip ab/adduction; and ankle rotation in the left lower limb; Hip ab/adduction; and Hip rotation in the right lower limb*
		Sedentary Participants	*Table 4.4.12*	*Pelvic obliquity; and Hip ab/adduction in the left lower limb*
	Mid-Swing	*All participants*	*Table 4.4.13*	*Hip Flexion/Extension; Ankle Dorsi/Plantar Flexion; Hip Ab/Adduction; Knee Ab/Adduction and Knee Rotation in the left lower limb; Ankle Dorsi/Plantar Flexion; Hip Ab/Adduction; and Knee Ab/Adduction in the right lower limb*
		Active Participants	*Table 4.4.14*	*Hip flexion/extension; Hip ab/adduction; Knee ab/adduction; and Knee rotation in the left lower limb; Ankle dorsi/plantarflexion; Knee ab/adduction; and Pelvic rotation in the right lower limb*
		Sedentary Participants	*Table 4.4.15*	*Pelvic tilt in the left lower limb; Pelvic Obliquity; and Hip ab/adduction in the right lower limb*

4.5. Section B: Spatio-Temporal Readings pre- and post-

The Paired Samples T-test was again used to compare mean pre-scores with mean post-scores. The null hypothesis specifies that the mean scores vary marginally between the two sessions and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean scores vary significantly between the two sessions and is accepted if the p-value is smaller than the 0.05 criterion.

The tables within this section (Section B) were divided into three tables:

- Pre- and post- temporal parameters for all the participants (**Table 4.5.1),**
- Pre- and post- temporal parameters for active participants (**Table 4.5.2**),
- Pre- and post- temporal parameters for sedentary participants (**Table 4.5.3**).

A Paired Samples T-test was used to compare the mean spatio-temporal pre-scores with mean post-scores. Significant changes ($p < 0.05$) in the readings included: Heart Rate; Cadence; Step Time (Left); Walking Speed (Left and Right); and Stride Time (Left and Right).

Table 4.5.1: Comparison of all mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)

		Mean	N	S.D.	P value
Heart Rate (beats/min)	Pre	73.78	40	14.129	<0.001
	Post	160.20	40	24.843	
Cadence (steps/min)	Pre	106.23	40	10.717	0.002
	Post	110.44	40	10.101	
Step Time (Left) (seconds)	Pre	0.58	40	0.060	<0.001
	Post	0.55	40	0.050	
Walking Speed (Left) (metres/second)	Pre	1.17	40	0.161	0.043
	Post	1.21	40	0.153	
Walking Speed (Right) (metres/second)	Pre	1.15	40	0.165	0.024
	Post	1.20	40	0.149	
Stride Time (Left) (seconds)	Pre	1.14	40	0.118	0.023
	Post	1.10	40	0.103	
Stride Time (Right) (seconds)	Pre	1.14	40	0.123	0.002
	Post	1.09	40	0.103	

All the results are represented in Appendix 2 Table 2.21

A Paired Samples T-test was used to compare the mean spatio-temporal pre-scores with mean post-scores of active individuals. Significant changes ($p < 0.05$) in the readings included: Cadence; Step Time (Left); and Stride Time (Right).

Table 4.5.2: Comparison of Active participants' mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)

		Mean	N	S.D.	P value
Cadence (steps/min)	Pre	106.30	31	8.817	0.02
	Post	109.83	31	9.500	
Step Time (Left) (seconds)	Pre	0.57	31	0.050	0.00
	Post	0.55	31	0.044	
Stride Time (Right) (seconds)	Pre	1.14	31	0.100	0.02
	Post	1.10	31	0.100	

All the results are represented in Appendix 2 Table 2.22

A Paired Samples T-test was used to compare the mean spatio-temporal pre-scores with mean post-scores of sedentary individuals. Significant changes ($p < 0.05$) in the readings included: Cadence; Step Time (Left); and Stride Time (Right).

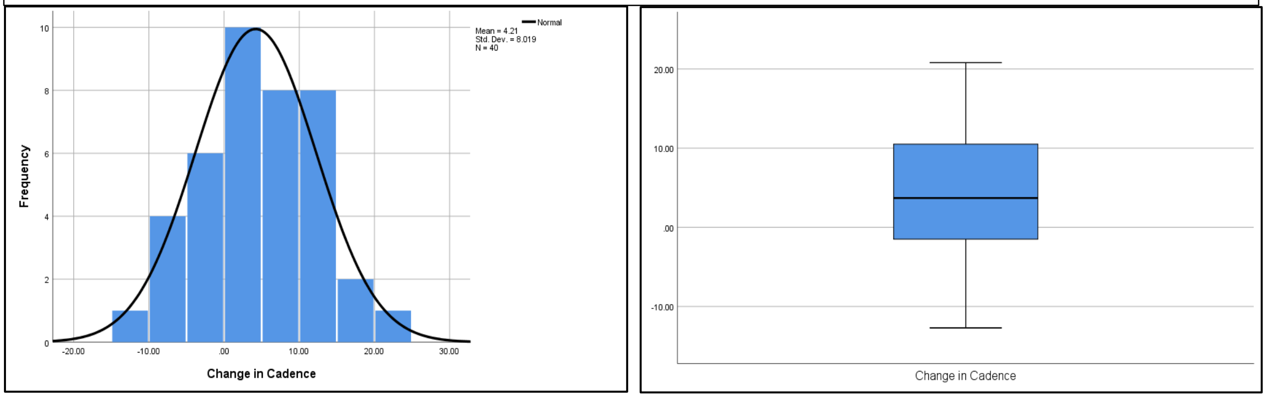
Table 4.5.3: Comparison of Sedentary participants' mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)

		Mean	N	S.D	P value
Stride Time (Right) (seconds)	Pre	1.16	9	0.191	0.04
	Post	1.07	9	0.117	

All the results are represented in Appendix 2 Table 2.23

The spatio-temporal data collected for cadence demonstrated an increase in number of steps per minute once participants were fatigued. The cadence changed from 106 steps per minute to 110. This increase in 4 steps per minute can also be observed in the box-plot and the frequency distribution curve below (Diagram 4.0.). Both diagrams indicate that the mean increase in steps frequency was that of 4.21 steps/minute. Diagram 4.0. represents the readings of the entire population sample of the research.

Diagram 4.0.: Distribution Curve and Box-plot outlining change in Cadence



4.5.1. Heart Rate scores (comparison between pre- and post-)

A Paired Samples T-test was used to compare the mean Heart Rate pre-scores with mean post-scores of both active and sedentary individuals. Significant changes ($p < 0.05$) in the HR readings of both active and sedentary individuals was noted.

Table 4.5.4: Comparison of participants' mean pre- and post- Heart Rate Scores (Paired Samples T test)

Lifestyle	HR	Mean (bpm)	S.D.	P value
Sedentary	HR[1] pre	77.67	22.215	<0.001
	HR post	157.11	30.571	
Active	HR pre	72.65	11.047	<0.001
	HR post	161.10	23.440	

4.5.2. RPE vs HR

The One Way ANOVA test was used to compare mean heart rates between different RPEs of all the participants. The null hypothesis specifies that the mean heart rates vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

Table 4.5.4.1.: Correlation of RPE and their corresponding HR scores of all participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean Heart Rate (BPM)	S. D.	Std. Error
Description	Value				
No exertion	6	65	86.31	22.428	2.782
Extremely Light	7	26	114.62	28.991	5.686
	8	22	115.59	19.990	4.262
Very Light	9	26	124.12	20.912	4.101
	10	8	115.63	28.874	10.208
Light	11	32	138.00	25.352	4.482
	12	40	136.68	26.603	4.206
Somewhat hard	13	21	138.67	22.462	4.902
	14	47	141.89	27.683	4.038
Hard	15	52	142.77	26.838	3.722

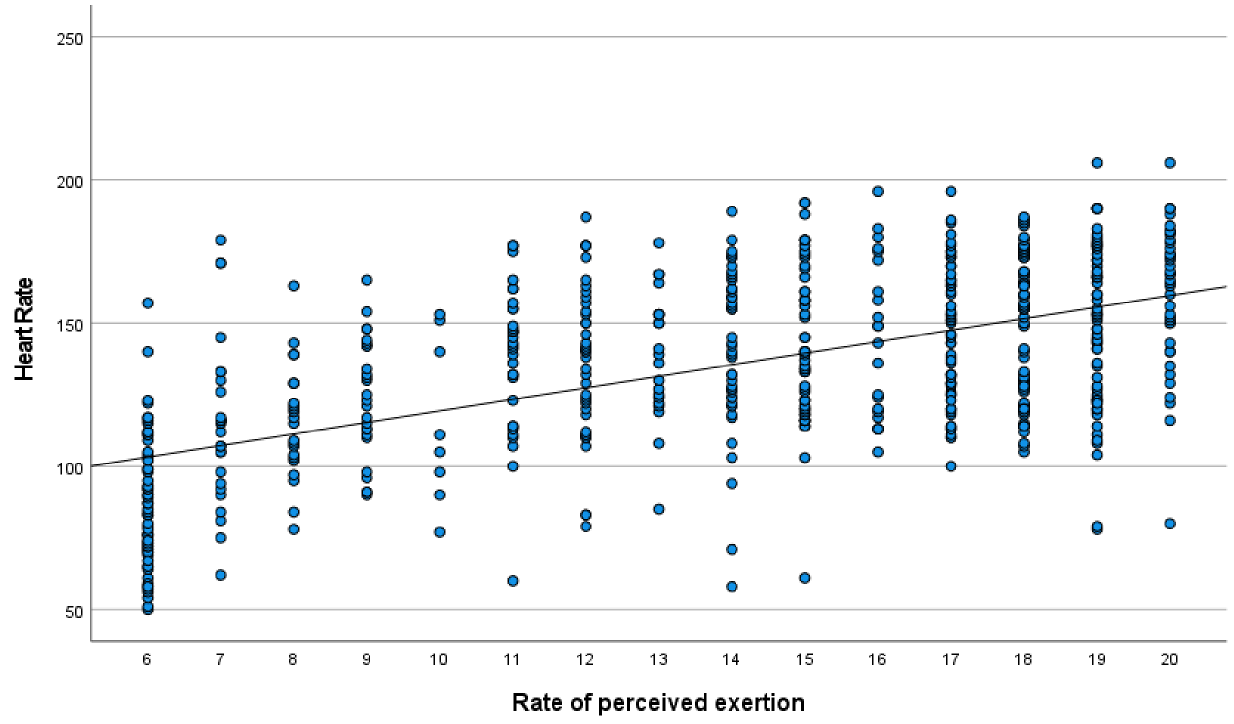
[1] HR: Heart Rate

	16	22	144.50	27.640	5.893
Very hard	17	62	145.44	23.570	2.993
	18	75	147.36	24.448	2.823
Extremely hard	19	68	148.94	27.633	3.351
Maximal exertion	20	40	160.20	24.843	3.928

$F(14, 591) = 27.309$, $p < 0.001$

On average, the mean heart rate is increasing together with RPE scores. Moreover, the mean heart rates vary significantly between RPEs since the p-value (approx. 0) is smaller than the 0.05 level of significance. A Pearson correlation demonstrated a positive coefficient (0.572) indicating that an increase in RPEs results in an increase in the heart rates. This is also displayed in the scatter plots below (**Diagram 4.1.**). Moreover, this positive relationship is significant since the p-value (approx. 0) is smaller than the 0.05 level of significance. The gradient of the regression line (4.03) indicates that for every 1 unit increase in RPE, the heart rate is expected to increase by approximately 4 units.

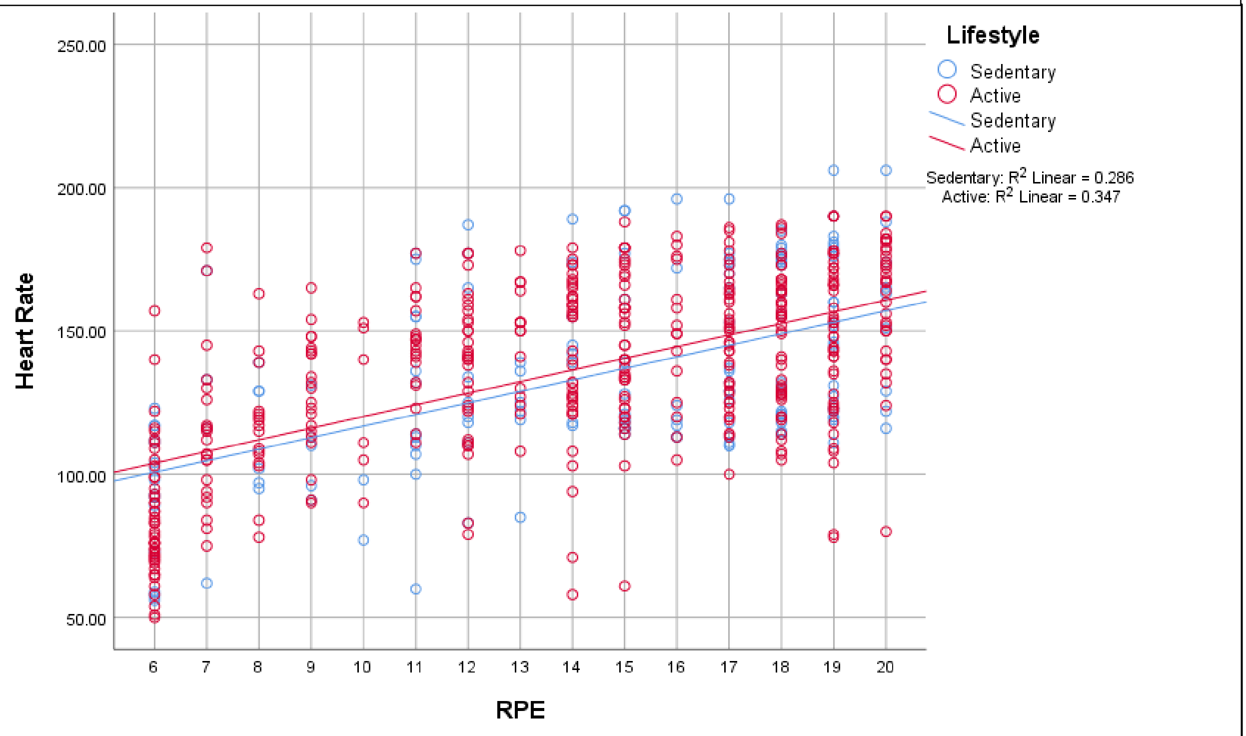
Diagram 4.1.: Scatter plot of HR against RPE along with Pearson Correlation Test



Pearson Correlation

		Rate of perceived exertion
Heart Rate	Pearson Correlation	0.572
	P-value	<0.001

Diagram 4.2.: Scatter plot of HR against RPE for Active and Sedentary Participants



The One Way ANOVA test was used to compare mean heart rates between different RPEs of Active individuals. The null hypothesis specifies that the mean heart rates vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

Table 4.5.4.2.: Correlation of RPE and their corresponding HR scores of active participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean (BPM)	S. D.	Std. Error
Description	Value				
No exertion	6	49	84.67	22.022	3.146
Extremely Light	7	22	113.55	26.457	5.641
	8	16	115.75	20.863	5.216
Very Light	9	21	127.90	20.462	4.465
	10	6	125.00	26.480	10.810
Light	11	20	144.10	16.540	3.698
	12	31	137.00	24.716	4.439
Somewhat hard	13	15	145.73	20.005	5.165
	14	39	140.77	28.365	4.542
Hard	15	39	143.97	25.886	4.145
	16	15	148.33	24.790	6.401
Very hard	17	43	146.12	21.856	3.333
	18	48	147.73	22.675	3.273
Extremely hard	19	47	147.74	27.527	4.015
Maximal exertion	20	31	161.10	23.440	4.210

$F(14, 427) = 24.100$, $p < 0.001$

		Rate of perceived exertion
Heart Rate	Pearson Correlation	0.589
	P-value	<0.001

The Pearson correlation coefficient (0.589) is positive, indicating that an increase in RPEs results in an increase in the heart rates. This is clearly displayed in **Diagram 4.2**. Moreover, this positive relationship is significant since the p- value (approx. 0) is smaller than the 0.05 level of significance. The gradient of the regression line (4.06) indicates for every 1 unit increase in RPE, the heart rate is expected to increase by approximately 4 units.

The One Way ANOVA test was used to compare mean heart rates between different RPEs of Sedentary individuals. The null hypothesis specifies that the mean heart rates vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

Table 4.5.4.3.: Correlation of RPE and their corresponding HR scores of sedentary participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean (BPM)	S. D.	Std. Error
Description	Value				
No exertion	6	16	91.31	23.638	5.910
Extremely Light	7	4	120.50	45.273	22.637
	8	6	115.17	19.292	7.876
Very Light	9	5	108.20	15.738	7.038
	10	2	87.50	14.849	10.500
Light	11	12	127.83	34.034	9.825
	12	9	135.56	34.022	11.341
Somewhat hard	13	6	121.00	19.318	7.887
	14	8	147.38	25.042	8.854
Hard	15	13	139.15	30.337	8.414
	16	7	136.29	33.535	12.675
Very hard	17	19	143.89	27.650	6.343
	18	27	146.70	27.768	5.344
Extremely hard	19	21	151.62	28.361	6.189
Maximal exertion	20	9	157.11	30.571	10.190

$F(14, 149) = 5.317, p < 0.001$

		Rate of perceived exertion
Heart Rate	Pearson Correlation	0.535
	P-value	<0.001

The Pearson correlation coefficient (0.535) is positive, indicating that an increase in RPEs results in an increase in the heart rates. This is clearly displayed in the **Diagram 4.2**. Moreover, this positive relationship is significant since the p-value (approx. 0) is smaller than the 0.05 level of significance. The gradient of the regression line (4.02) indicates for every 1 unit increase in RPE, the heart rate is expected to increase by approximately 4 units.

4.5.3. Speed vs RPE

The One Way ANOVA test was used to compare mean speed readings between different RPEs. The null hypothesis specifies that the mean speed readings vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

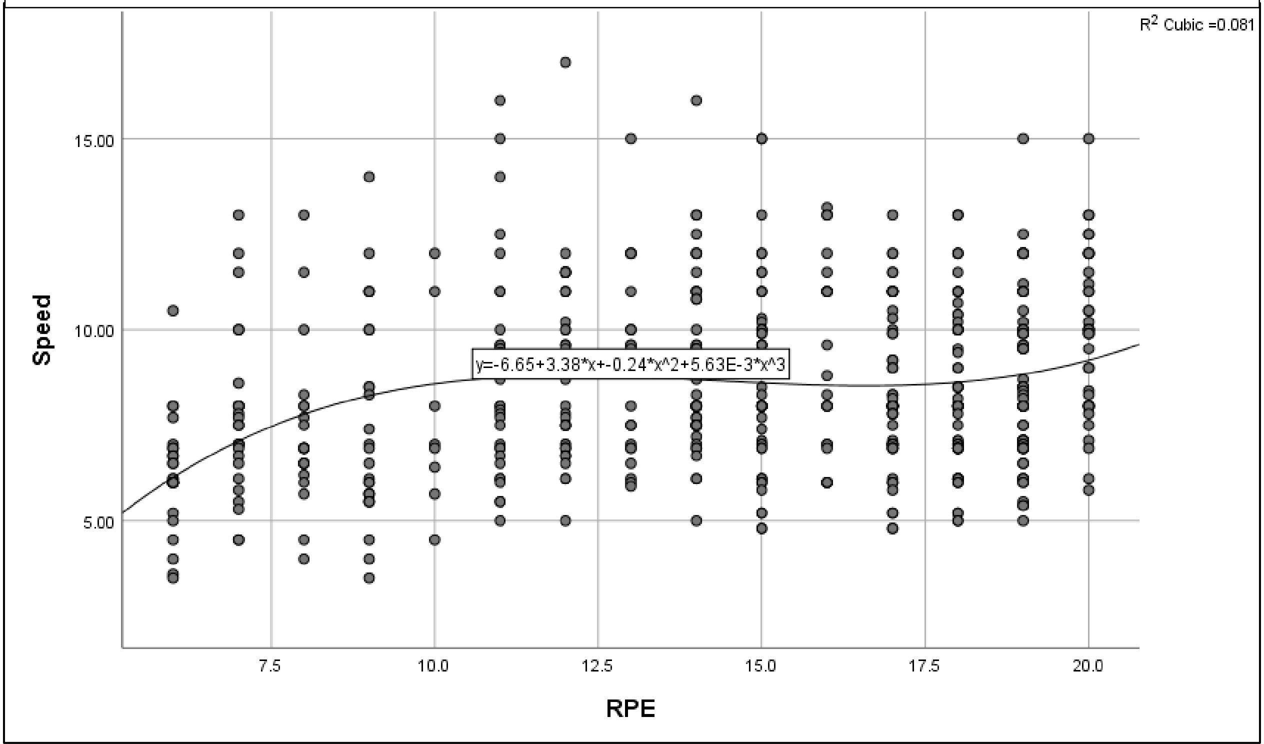
Table 4.5.4.4.: Correlation of RPE and their corresponding Speed scores of all participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean	S. D.	Std. Error
Description	Value		(m/s)		
No exertion	6	65	2.4831	3.19959	.39686
Extremely Light	7	26	7.7077	2.14157	.42000
	8	22	7.3136	2.03711	.43431
Very Light	9	26	7.5308	2.69381	.52830
	10	8	7.6875	2.57817	.91152
Light	11	32	8.8094	2.78143	.49169
	12	40	8.9075	2.32185	.36712
Somewhat hard	13	21	8.9524	2.46488	.53788
	14	47	9.1298	2.23382	.32584
Hard	15	52	8.6654	2.41286	.33460
	16	22	9.1955	2.51045	.53523
Very hard	17	62	8.3597	1.95427	.24819
	18	75	8.2933	2.02500	.23383
Extremely hard	19	68	8.5515	2.11198	.25611
Maximal exertion	20	40	9.7650	2.17545	.34397

$F(14, 591) = 29.630$, $p < 0.001$

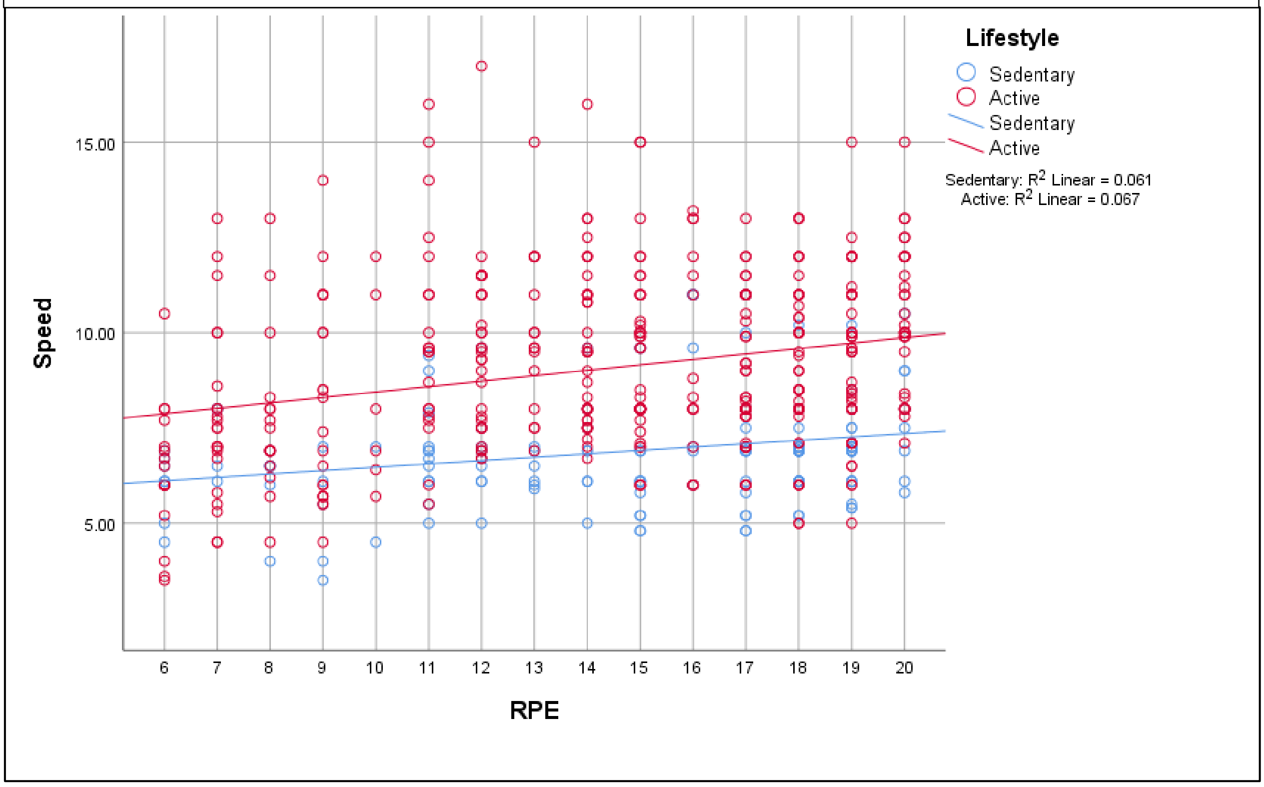
On average, the mean speed scores are increasing along with the increase in RPEs. Moreover, the speed scores vary significantly between RPEs since the p-value (approx. 0) is smaller than the 0.05 level of significance. A Pearson correlation demonstrated a positive coefficient (0.447) indicating that an increase in RPEs results in an increase in the speed. The gradient of the regression line (0.12) indicates for every 1 unit increase in RPE, the speed is expected to increase by approximately 0.12 units. When separating active and sedentary scores, the positive relationship between Speed and RPE is steeper and has a more distinct shape than the sedentary participants' scores. This is indicative that active participants selected higher speeds than their sedentary counterparts. This is clearly displayed in the **Diagram 4.4.** scatter plot.

Diagram 4.3.: Scatter plot of Speed against RPE along with Pearson Correlation Test



Pearson Correlation		
		Rate of perceived exertion
Speed	Pearson Correlation	0.447
	P-value	<0.001

Diagram 4.4.: Scatter plot of HR against RPE for Active and Sedentary Participants



The One Way ANOVA test was used to compare mean speed readings between different RPEs of Active participants. The null hypothesis specifies that the mean speed readings vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

Table 4.5.4.5.: Correlation of RPE and their corresponding Speed scores of Active participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean (m/s)	S. D.	Std. Error
Description	Value				
No exertion	6	49	2.3184	3.23449	.46207
Extremely Light	7	22	7.8091	2.29096	.48843
	8	16	7.7812	2.14141	.53535
Very Light	9	21	8.0810	2.64473	.57713
	10	6	8.3333	2.58431	1.05504
Light	11	20	9.9450	2.83149	.63314
	12	31	9.5129	2.21401	.39765
Somewhat hard	13	15	9.9733	2.16579	.55921
	14	39	9.5641	2.13165	.34134
Hard	15	39	9.3718	2.21941	.35539
	16	15	9.3200	2.69767	.69654
Very hard	17	43	8.8674	1.79241	.27334
	18	48	9.1063	2.01182	.29038
Extremely hard	19	47	9.2511	2.08263	.30378
Maximal exertion	20	31	10.3935	1.89437	.34024

$F(14, 427) = 29.584$, $p < 0.001$

		Rate of perceived exertion
Speed	Pearson Correlation	0.496
	P-value	<0.001

The Pearson correlation coefficient (0.496) is positive, indicating that an increase in RPEs results in an increase in the speed. This is clearly displayed in **Diagram 4.4.** scatter plot. Moreover, this positive relationship is significant since the p-value (approx. 0) is smaller than the 0.05 level of significance. The gradient of the regression line (0.14) indicates for every 1 unit increase in RPE, the speed is expected to increase by approximately 0.14 units.

The One Way ANOVA test was used to compare mean speed readings between different RPEs of Sedentary participants. The null hypothesis specifies that the mean speed readings vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

Table 4.5.4.6.: Correlation of RPE and their corresponding Speed scores of Sedentary participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean	S. D.	Std. Error
Description	Value		(m/s)		
No exertion	6	16	2.9875	3.13706	.78427
Extremely Light	7	4	7.1500	.99499	.49749
	8	6	6.0667	1.05198	.42947
Very Light	9	5	5.2200	1.45499	.65069
	10	2	5.7500	1.76777	1.25000
Light	11	12	6.9167	1.30442	.37655
	12	9	6.8222	1.25974	.41991
Somewhat hard	13	6	6.4000	.47329	.19322
	14	8	7.0125	1.39636	.49369
Hard	15	13	6.5462	1.63024	.45215
	16	7	8.9286	2.22614	.84140
Very hard	17	19	7.2105	1.85379	.42529
	18	27	6.8481	.98268	.18912
Extremely hard	19	21	6.9857	1.11458	.24322
Maximal exertion	20	9	7.6000	1.67631	.55877

$F(14, 149) = 20.311$, $p < 0.001$

		Rate of perceived exertion
Speed	Pearson Correlation	0.459
	P-value	<0.001

The Pearson correlation coefficient (0.459) is positive, indicating that an increase in RPEs results in an increase in the speed. This is clearly displayed in the **Diagram 4.4.** scatter plot. Moreover, this positive relationship is significant since the p-value (approx. 0) is smaller than the 0.05 level of significance. The gradient of the regression line (0.09) indicates for every 1 unit increase in RPE, the speed is expected to increase by approximately 0.09 units.

4.5.4. SPO_2 vs RPE

The One Way ANOVA test was used to compare mean SPO_2 readings between different RPEs. The null hypothesis specifies that the mean SPO_2 readings vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

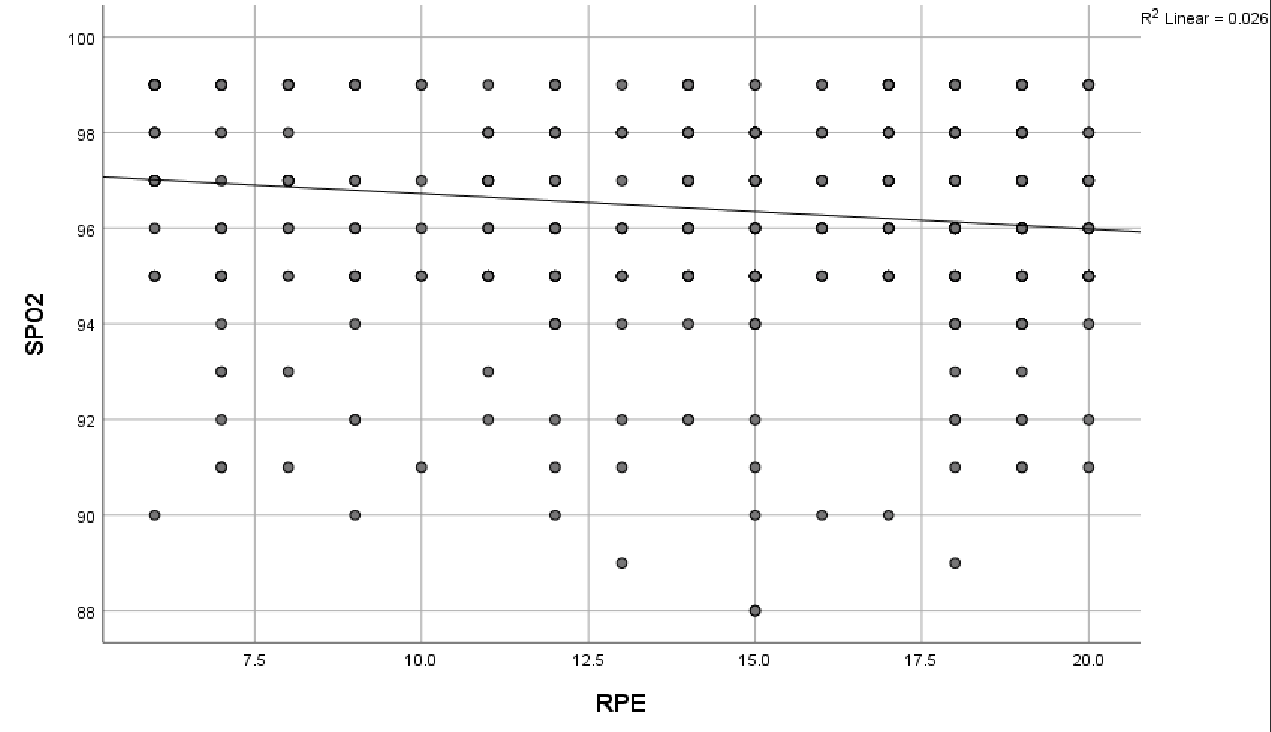
Table 4.5.4.7.: Correlation of RPE and their corresponding SPO_2 scores of all participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean	S. D.	Std. Error
Description	Value		(%)		
No exertion	6	65	98.15	1.603	.199
Extremely Light	7	26	95.88	2.582	.506
	8	22	96.86	2.031	.433
Very Light	9	26	95.96	2.425	.475
	10	8	95.88	2.588	.915
Light	11	32	96.22	1.539	.272
	12	40	96.03	2.142	.339
Somewhat hard	13	21	95.52	2.502	.546
	14	47	96.66	1.857	.271
Hard	15	52	95.79	2.444	.339
	16	22	96.32	1.912	.408
Very hard	17	62	96.92	1.682	.214
	18	75	96.20	1.903	.220
Extremely hard	19	68	96.15	1.910	.232
Maximal exertion	20	40	95.90	1.795	.284

$F(14, 591) = 21.290$, $p < 0.001$

A significant negative relationship ($p < 0.001$) can be observed as participants' oxygen levels (SPO_2) decreased as the exercise progressed and higher RPE scores were achieved. A Pearson correlation demonstrated a negative coefficient (-0.164) indicating that an increase in RPEs results in an increase in the SPO_2. The gradient of the regression line (0.07) indicates for every 1 unit increase in RPE, the SPO_2 is expected to decrease by approximately 0.07 units. Once active participants' and sedentary participants' readings are separated, the gradient of the negative relationships vary significantly with the active sample adopting a steeper gradient than their sedentary counterparts (**Diagram 4.6.**). This shed light on the fact that active participants achieved fatigue on a cardio-respiratory level rather than lower-limb fatigue.

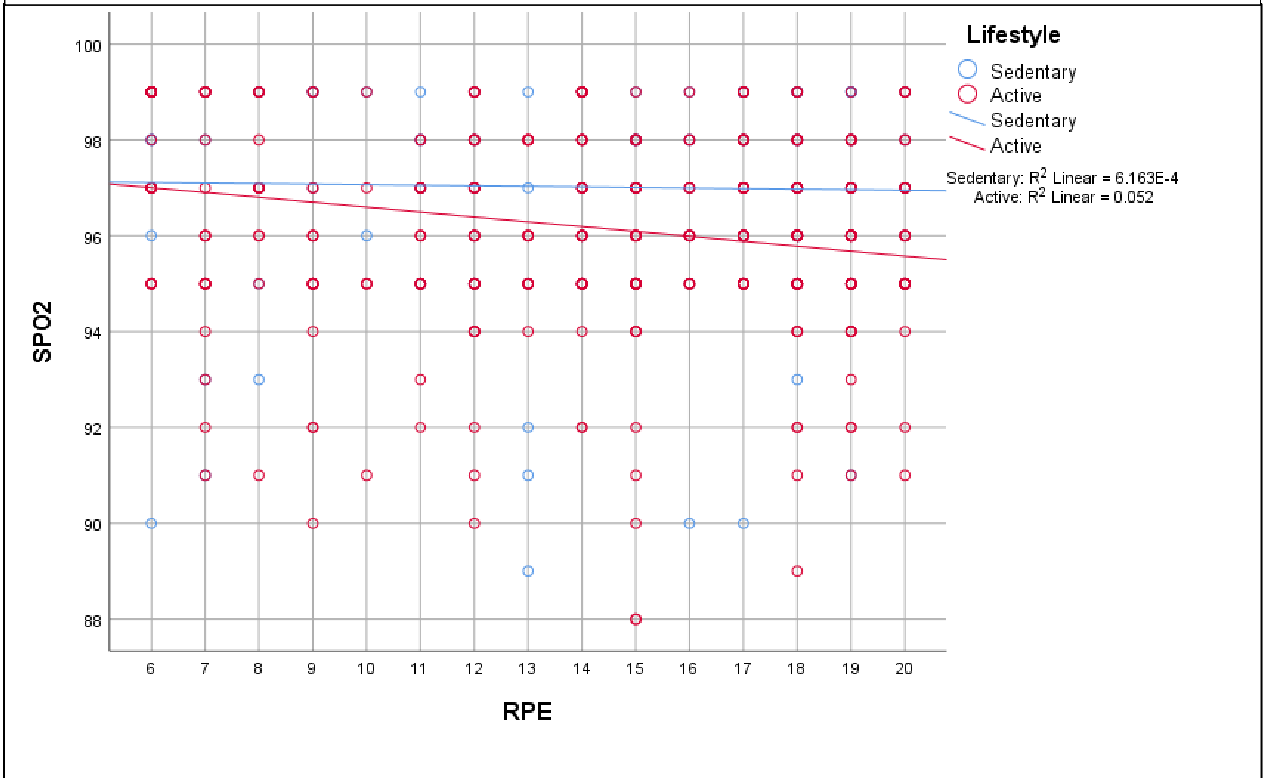
Diagram 4.5.: Scatter plot of SPO_2 against RPE along with Pearson Correlation Test



Pearson Correlation

		Rate of perceived exertion
SPO_2	Pearson Correlation	-0.164
	P-value	<0.001

Diagram 4.6.: Scatter plot of SPO_2 against RPE for Active and Sedentary Participants



between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

Table 4.5.4.8.: Correlation of RPE and their corresponding SPO_2 scores of Active participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean	S. D.	Std. Error
Description	Value		(%)		
No exertion	6	49	98.24	1.331	.190
Extremely Light	7	22	96.00	2.390	.510
	8	16	96.94	1.982	.496
Very Light	9	21	95.33	2.244	.490
	10	6	95.33	2.658	1.085
Light	11	20	95.80	1.542	.345
	12	31	95.84	2.282	.410
Somewhat hard	13	15	96.20	1.424	.368
	14	39	96.59	1.916	.307
Hard	15	39	95.21	2.515	.403
	16	15	96.40	1.242	.321
Very hard	17	43	96.67	1.322	.202
	18	48	95.77	1.992	.288
Extremely hard	19	47	95.66	1.698	.248
Maximal exertion	20	31	95.77	1.802	.324

$F(14, 427) = 23.209$, $p < 0.001$

		Rate of perceived exertion
SPO_2	Pearson Correlation	-.228
	P-value	.000

The Pearson correlation coefficient (-0.228) is negative, indicating that an increase in RPEs results in an increase in the SPO_2. This is clearly displayed in **Diagram 4.6.** scatter plot. Moreover, this positive relationship is significant since the p-value (approx. 0) is smaller than the 0.05 level of significance. The gradient of the regression line (0.1) indicates for every 1 unit increase in RPE, the SPO_2 is expected to decrease by approximately 0.1 units.

The One Way ANOVA test was used to compare mean SPO_2 readings between different RPEs of Sedentary participants. The null hypothesis specifies that the mean SPO_2 readings vary marginally between the RPEs and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores provided to the statement vary significantly between the groups, and is accepted if the p-value is less than the 0.05 criterion.

Table 4.5.4.9.: Correlation of RPE and their corresponding SPO_2 scores of Sedentary participants (One Way ANOVA)

Rate of Perceived Exertion		Number of Participant scores for current RPE value	Mean	S. D.	Std. Error
Description	Value		(%)		
No exertion	6	16	97.88	2.277	.569
Extremely Light	7	4	95.25	3.862	1.931
	8	6	96.67	2.338	.955
Very Light	9	5	98.60	.894	.400
	10	2	97.50	2.121	1.500
Light	11	12	96.92	1.311	.379
	12	9	96.67	1.500	.500
Somewhat hard	13	6	93.83	3.817	1.558
	14	8	97.00	1.604	.567
Hard	15	13	97.54	.967	.268
	16	7	96.14	3.024	1.143
Very hard	17	19	97.47	2.245	.515
	18	27	96.96	1.480	.285
Extremely hard	19	21	97.24	1.947	.425
Maximal exertion	20	9	96.33	1.803	.601

$F(14, 149) = 2.092, p < 0.015$

		Rate of perceived exertion
SPO_2	Pearson Correlation	-.039
	P-value	.618

The Pearson correlation coefficient (-0.39) is negative, indicating that an increase in RPEs results in a decrease in the SPO_2. This is clearly displayed in **Diagram 4.6.** scatter plot. Moreover, this positive relationship is significant since the p-value (approx. 0) is smaller than the 0.05 level of significance. The gradient of the regression line (0.01) indicates for every 1 unit increase in RPE, the SPO_2 is expected to decrease by approximately 0.10 units.

4.5.5. Summary of Section B: Spatio-Temporal Readings pre- and post-

Type of data	**Instance observed**	**Participant population**	**Table**	**Observation**
Spatio-Temporal Parameters	Spatio-Temporal Parameters	All participants	Table 4.5.1	Heart Rate; Cadence; Step Time (Left); Walking Speed (Left and Right); and Stride Time (Left and Right)
		Active Participants	Table 4.5.2	Cadence; Step Time (Left); and Stride Time (Right)
		Sedentary Participants	Table 4.5.3	Cadence; Step Time (Left); and Stride Time (Right)
Test Measures	HR scores	All participants	Table 4.5.4	Significant change in the HR readings of both active and sedentary individuals observed.
Test Measures vs RPE	RPE vs HR	All participants	Table 4.5.4. 1	Significant positive relationship observed.
		Active Participants	Table 4.5.4. 2	Significant positive relationship observed.
		Sedentary Participants	Table 4.5.4. 3	Significant positive relationship observed.
	Speed vs RPE	All participants	Table 4.5.4. 4	Significant positive relationship observed.
		Active Participants	Table 4.5.4. 5	Significant positive relationship observed.
		Sedentary Participants	Table 4.5.4. 6	Significant positive relationship observed.
	SPO_2 vs RPE	All participants	Table 4.5.4. 7	Significant negative relationship observed.
		Active Participants	Table 4.5.4. 8	Significant negative relationship observed.
		Sedentary Participants	Table 4.5.4. 9	Significant negative relationship observed.

4.6. Active vs Sedentary (Fatigue-induced Changes in Kinematic and Kinetic data)

The following section demonstrates a comparison of the change in Capture data results between active and sedentary individuals. The score difference was computed for all movements of each participant by subtracting the pre-score from the post-score. A positive score difference indicates that the post score is larger than the pre-score; while a negative score difference indicates that the post score is smaller than the pre-score The Independent Samples T-test was then used to compare the mean score differences between two groups of participants (Sedentary, Active). The null hypothesis specifies that the mean score differences vary marginally between the two groups and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that the mean score differences vary significantly between the two groups and is accepted if the p-value is smaller the 0.05 level of significance.

The following section is divided as follows:

- Changes in Heel-strike,
- Changes in Mid-stance,
- Changes in Weight-transference,
- Changes in Toe-off,
- Changes in Mid-swing.

4.6.1. Changes in Heel-strike

An Independent Samples T-test was used to compare the mean rate of change in kinematic and kinetic data during Mid-Swing between Active and Sedentary participants. Significant changes ($p < 0.05$) between Active and Sedentary movements captured included:

- Ankle ab/adduction

No further significant changes were noted within this instance of gait.

Table 4.6.1.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Heel-Strike (Independent Samples T-test)

		N	Mean	S.D.	P value
Ankle Ab/Adduction (Left) (degrees)	Active	31	-0.12	0.92144	0.010
	Sedentary	9	0.75	0.73429	
Ankle Ab/Adduction (Right) (degrees)	Active	31	-0.28	0.87813	0.013
	Sedentary	9	0.88	1.90771	
All the results are represented in Appendix 2 Table 2.16.					

4.6.2. Changes in Mid-Stance

An Independent Samples T-test was used to compare the mean rate of change in kinematic and kinetic data during Mid-Stance between Active and Sedentary participants. Significant changes ($p < 0.05$) between Active and Sedentary movements captured included:

- knee flexion/extension; ankle dorsi/plantar flexion; hip ab/adduction; knee ab/adduction (right); ankle ab/adduction; hip rotation; knee rotation; ankle rotation (left)

No further significant changes were noted within this instance of gait.

Table 4.6.2.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Mid-Stance (Independent Samples T-test).

		N	Mean	S.D.	sig	P value
Knee Flexion/Extension (Left) (degrees)	Active	31	0.08	2.55572	0.540	0.019
	Sedentary	9	3.35	3.30586		
Ankle Dorsi/Plantar Flexion (Left)	Active	31	-0.33	1.76345	0.421	0.020

(degrees)	Sedentary	9	1.13	1.40967		
Hip Ab/Adduction (Left) (degrees)	Active	31	-0.12	1.45990	0.266	0.040
	Sedentary	9	0.87	1.07572		
Knee Ab/Adduction (Right) (degrees)	Active	31	0.14	1.03018	0.550	0.033
	Sedentary	9	-0.63	0.81532		
Ankle Ab/Adduction (Left) (degrees)	Active	31	-0.26	1.02723	0.643	0.030
	Sedentary	9	0.74	1.09671		
Hip Rotation (Left) (degrees)	Active	31	1.08	5.84598	0.435	0.035
	Sedentary	9	-1.83	2.42342		
Knee Rotation (Left) (degrees)	Active	31	-1.88	4.87077	0.901	0.007
	Sedentary	9	2.66	3.60289		
Ankle Rotation (Left) (degrees)	Active	31	1.08	4.00094	0.776	0.008
	Sedentary	9	-3.12	3.52642		

All the results are represented in Appendix 2 Table 2.17.

4.6.3. Changes in Weight-transference

An Independent Samples T-test was used to compare the mean rate of change in kinematic and kinetic data during weight-transference between Active and Sedentary participants. Significant changes ($p < 0.05$) between Active and Sedentary movements captured included:

- hip rotation (right)

No further significant changes were noted within this instance of gait.

Table 4.6.3.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Weight Transferance (Independent Samples T-test)

		N	Mean	S.D.	sig	P value
Hip Rotation (Right) (degrees)	Active	31	-1.94	4.45548	0.073	0.032
	Sedentary	9	0.06	1.24595		

All the results are represented in Appendix 2 Table 2.18.

4.6.4. Changes in Toe-off

An Independent Samples T-test was used to compare the mean rate of change in kinematic and kinetic data during Toe-off between Active and Sedentary participants. No significant changes ($p < 0.05$) were noted within this instance of gait between Active and Sedentary participants (All the results are represented in Appendix 2 Table 2.19.).

4.6.5. Changes in Mid-swing

An Independent Samples T-test was used to compare the mean rate of change in kinematic and kinetic data during Mid-Swing between Active and Sedentary participants. Significant changes ($p < 0.05$) between Active and Sedentary movements captured included:

- pelvic tilt, and pelvic obliquity

No further significant changes were noted within this instance of gait.

Table 4.6.5.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Mid-Swing (Independent Samples T-test)

		N	Mean	S.D.	sig	P value
Pelvic Tilt (Left) (degrees)	Active	31	0.11	1.73730	0.951	0.045
	Sedentary	9	-1.28	1.64360		
Pelvic Obliquity (Right) (degrees)	Active	31	0.40	1.43699	0.296	0.008
	Sedentary	9	-0.89	1.03977		
All the results are represented in Appendix 2 Table 2.20.						

4.6.6. Summary of Active vs Sedentary (Fatigue-induced Changes in Kinematic and Kinetic data)

Type of data	**Instance observed**		**Table**	**Observation**
Vicon Data	Changes in:	Heel-strike	Table 4.6.1	ankle ab/adduction
		Mid-stance	Table 4.6.2	knee flexion/extension; ankle dorsi/plantar flexion; hip ab/adduction; knee ab/adduction (right); ankle ab/adduction; hip rotation; knee rotation; ankle rotation (left)
		Weight-transference	Table 4.6.3	hip rotation
		Mid-swing	Table 4.6.5	pelvic tilt; pelvic obliquity

4.7. Summary of Results

Section	Type of data	Instance observed	Participant population	Table	Observation
Section A: Vicon Data	Captures Pre vs Captures Post	Heel-strike	All participants	Table 4.4.1	GRF along the Z-axis both left and right lower limb
			Active Participants	Table 4.4.2	GRF along the Z-axis both left and right lower limb
			Sedentary Participants	Table 4.4.3	Knee flexion and extension; Pelvic obliquity; and Ankle ab/adduction in the left lower limb.
		Mid-Stance	All participants	Table 4.4.4	GRF along the Z-axis in the left lower limb,
			Active Participants	Table 4.4.5	Knee Rotation; and GRF along the Z-axis in the left lower limb,
			Sedentary Participants	Table 4.4.6	Knee flexion and extension; Ankle dorsi/plantarflexion; Hip ab/adduction; and ankle rotation in the left lower limb; Knee ab/adduction in the right lower limb.
		Weight-transference	All participants	Table 4.4.7	Pelvic Obliquity and Pelvic Rotation in the left lower limb; Ankle dorsi/plantarflexion; and Hip rotation in the right lower limb
			Active Participants	Table 4.4.8	Hip ab/adduction; ankle ab/adduction; pelvic rotation and ankle rotation in the left lower limb, Ankle dorsi/plantarflexion; GRF along the X-axis; and Hip rotation in the right lower limb
			Sedentary Participants	Table 4.4.9	Pelvic obliquity; and Hip rotation in the left lower limb; Ankle dorsi/plantarflexion in the right lower limb
		Toe-off	All participants	Table 4.4.10	Ankle dorsi/plantarflexion; Pelvic Obliquity and Hip ab/adduction in the

					left lower limb; Hip rotation in the right lower limb
			Active Participants	Table 4.4.11	Ankle dorsi/plantarflexion; Pelvic Obliquity; Hip ab/adduction; and ankle rotation in the left lower limb; Hip ab/adduction; and Hip rotation in the right lower limb
			Sedentary Participants	Table 4.4.12	Pelvic obliquity; and Hip ab/adduction in the left lower limb
		Mid-Swing	All participants	Table 4.4.13	Hip Flexion/Extension; Ankle Dorsi/Plantar Flexion; Hip Ab/Adduction; Knee Ab/Adduction and Knee Rotation in the left lower limb; Ankle Dorsi/Plantar Flexion; Hip Ab/Adduction; and Knee Ab/Adduction in the right lower limb
			Active Participants	Table 4.4.14	Hip flexion/extension; Hip ab/adduction; Knee ab/adduction; and Knee rotation in the left lower limb; Ankle dorsi/plantarflexion; Knee ab/adduction; and Pelvic rotation in the right lower limb
			Sedentary Participants	Table 4.4.15	Pelvic tilt in the left lower limb; Pelvic Obliquity; and Hip ab/adduction in the right lower limb
Section B: Spatio-Temporal Readings pre- and post-	Spatio-Temporal Parameters	Spatio-Temporal Parameters	All participants	Table 4.5.1	Heart Rate; Cadence; Step Time (Left); Walking Speed (Left and Right); and Stride Time (Left and Right)
			Active Participants	Table 4.5.2	Cadence; Step Time (Left); and Stride Time (Right)
			Sedentary Participants	Table 4.5.3	Cadence; Step Time (Left); and Stride Time (Right)
	Test Measures	HR scores	All participants	Table 4.5.4	Significant change in the HR readings of both active and sedentary individuals observed.
		RPE vs HR	All participants	Table 4.5.4. 1	Significant positive relationship observed.

	Test Measures vs RPE		Active Participants	Table 4.5.4. 2	Significant positive relationship observed.
			Sedentary Participants	Table 4.5.4. 3	Significant positive relationship observed.
		Speed vs RPE	All participants	Table 4.5.4. 4	Significant positive relationship observed.
			Active Participants	Table 4.5.4. 5	Significant positive relationship observed.
			Sedentary Participants	Table 4.5.4. 6	Significant positive relationship observed.
		SPO_2 vs RPE	All participants	Table 4.5.4. 7	Significant negative relationship observed.
			Active Participants	Table 4.5.4. 8	Significant negative relationship observed.
			Sedentary Participants	Table 4.5.4. 9	Significant negative relationship observed.
Active vs Sedentary	Vicon Data	Changes in:	Heel-strike	Table 4.6.1	ankle ab/adduction
			Mid-stance	Table 4.6.2	knee flexion/extension; ankle dorsi/plantar flexion; hip ab/adduction; knee ab/adduction (right); ankle ab/adduction; hip rotation; knee rotation; ankle rotation (left)
			Weight-transference	Table 4.6.3	hip rotation
			Mid-swing	Table 4.6.5	pelvic tilt; pelvic obliquity

Chapter 5: Discussion

5.1. Introduction: Discussion

The discussion chapter is a critical section that provides an interpretation and synthesis of the results listed in the previous chapter. The researcher places the study's findings into context and explains their significance by looking back and comparing the results of the study with previous research whilst also suggesting future research directions.

The discussion chapter begins with a short introduction/appraisal of fatigue and how the data collected was influenced with some factors of fatigue. This section also provides an explanation of how the findings relate to previous bodies of literature and to the theoretical framework that underpins the study.

The chapter is laid out as follows:

- Section A: Vicon Data
    - Heel-strike
    - Mid-Stance
    - Weight-transference
    - Toe-off
    - Mid-Swing
- Section B: Test Measures
    - Spatio-Temporal Readings pre- and post-
    - Heart Rate
- Relationships of measures with RPE
    - RPE vs HR
    - SPO_2 vs RPE
    - Speed vs RPE
- Summary: Active vs Sedentary
- Asymmetry between Left and Right
- Conclusion

The interpretation and synthesis of the results are a critical part of the discussion chapter. The significance of the findings and their implications for clinical practice or future research are explained. This is achieved by including comparisons of the study's results with previous research. Similarities or differences are identified and are explained.

5.2. Introduction: Fatigue

Upon examination of pre-established literature on fatigue models, it becomes clear that repetitive isokinetic loading of muscle groups and mechanoreceptor dysfunction are the main physiological responses to fatigue. Then again, the data collected within this research is more indicative of cardiovascular fatigue, thus warranting the "general fatigue strategy" which was mentioned in the literature review (McLean, et al., 2007) (Borotikar, et al., 2008) (Wang, et al., 2012) (Schmitt, et al., 2013).

As stated earlier, the methodology incorporated within this research was aimed at making sure that participants actually achieve fatigue by reaching a "realistic exhaustive end point", and that the treadmill walking/running exercise being performed truly affects the muscle groups being observed. Comparable levels of fatigue between participants was hard to deduce: the RPE and the visual assessment conducted during the data collection session, suggest that this was the case with all subjects as all the participants were physically unable to continue their running/fast-walking tasks. In the subsequent sections, a detailed observation of the results is discussed. The data includes Kinematic and Kinetic data gathered from the Vicon Motion Capture system; Objective and Spatio-Temporal Parameters gathered pre- and post-exertion; and finally correlations between the objective measures and RPE.

5.3. Section A: Vicon Data

5.3.1. Heel-strike

From the results gathered for the current study, the first stage which was observed within the participants' gait cycle was heel strike. The Paired Samples T-test conducted on the mean scores of all the participants revealed a significant change in the GRF along the Z-axis (GRFz) of both the left and right lower limb (**Table 4.4.1**). This phenomenon is amongst the most researched and conforms to many studies including Bazuelo-Ruiz, et al., (2018), Zhou, et al., (2021) (Zhang, et al., 2022). Observations of changes in GRFz vary, with some authors revealing that vertical GRF (VGRF) values reduced with fatigue (Nicol, et al., 1991) (Christina, et al., 2001) (Gerlach, et al., 2005) (Morin, et al., 2011), while others observed higher values when runners were fatigued (Christina, et al., 2001). The study by Zhou, et al., (2021), researches the fatigue-induced variation in GRF kinetic by delving into the effect of muscle fatigue on the ability of the human musculoskeletal system to attenuate the heel-strike-generated shock waves. Another study conducted by Voloshin, et al., (1998), stated in their research that the more proximal the skeletal structures are, the more they are able to withstand effects of fatigue. Thus, they concluded that the running pattern may be modified in order to reduce the dynamic loading on the higher parts of the skeleton, with a possible aim of minimizing significant loading on the spine and head (Voloshin, et al., 1998). The active participants in the current study manifested this shock-attenuation by demonstrating only GRFz kinetic changes during heel-strike (**Table 4.4.2**).

The research by Bazuelo-Ruiz, et al., (2018) outlines how the knee and ankle joint kinematic parameters of gait within heel strike are important factors for joint stability (Bazuelo-Ruiz, et al., 2018). When observing all the participants within the current research, there were no significant changes in knee flexion and ankle dorsiflexion kinematics. Similar findings were observed in the research conducted by Nicol, et al., (1991), and Bazuelo-Ruiz, et al., (2018). A closer observation within the current research revealed that sedentary individuals demonstrated changes in knee and ankle kinematics at heel strike after an exercise session (**Table 4.4.3**). Again, these findings were similar to the observations made by Derrick, et al., (2002), Clansey, et al., (2012), Bazuelo-Ruiz, et al., (2018) and Zhiyong, et al., (2023). Accordingly, one can deduce that the knee joint plays a critical role in the body's ability to absorb shock and force dissipation during ground contact.

Lower knee flexion during landing may lead to a reduced time for shock attenuation, which has been associated with knee joint injuries, and a weaker knee joint power (Bazuelo-Ruiz, et al., 2018). On the other hand, Slater et al., (2018), reported that kinematic changes observed within their study was indicative as reflexive compensatory mechanisms whereby stress on the knee is shifted to accommodate the local cartilage and menisci. Thus, the stress and shock-attenuating responsibilities at the knees shift toward a more active muscular contraction.

Slater et al., (2018), observed the same principle at work within the ankles as well as small modifications in the ankle dorsiflexion (Edwards, et al., 2012) (Slater, et al., 2018). This subsequently alters the kinetic data at the ankle joint. Bazuelo-Ruiz, et al., (2018) describe how many authors showed that a higher ankle dorsiflexion resulted in an increase in the first peak force (GRFz), in line with the current study that demonstrated an increase in GRFz.

Contrastingly, other authors have indicated otherwise by observing lower dorsiflexion within the fatigued runner's ankle joint (Dutto, et al., 1997).

Sgnificant changes in Pelvic Obliquity; and Ankle Ab/Adduction (in the left lower limb) within the sedentary group were observed during the compilation of data (**Table 4.4.3**). This could have been due to a lack of fatigue-compensatory-mechanisms from the sedentary participants. In the study by Voloshin, et al., (1998), active participants were proven to have compensatory mechanisms in place which allow for kinetic and kinematic changes to occur during gait/running. These prevent a significant increase of dynamic loading towards the end of a 30 min long run and thus prevent injuries (Voloshin, et al., 1998). The same was also observed by Derrick, et al., (2002), who stated that although the movement pattern is altered with muscular fatigue, the goal of the task is preserved (Bazuelo-Ruiz, et al., 2018) (Slater, et al., 2018). Therefore, the previous studies confirm the conclusions derived from the data collection.

5.3.2. Mid-Stance

Similar to the findings during Heel Strike, all participants were found to have a significant change in the kinetic data of the GRF along the Z-axis in the left lower limb (**Table 4.4.4**). As the stage that succeeds the heel-strike phase, mid-stance demonstrates the progression of the distribution of the body weight during the single-leg phase of a gait cycle. Once again the proprioception and the neuromuscular return of the weight-bearing ankle altered the kinematic and kinetic data captured. The same results were discussed in the study by Wang, et al., (2012) who found that lower limb muscle fatigue had a significant 6% increase on the GRFz generated at the ankle (Wang, et al., 2012). The active population, within the current research, demonstrated changes in GRFz and knee rotation (**Table 4.4.5**) whilst the sedentary participants demonstrated more alterations, such as hip ab/adduction and knee flexion/extension and ab/adduction (**Table 4.4.6**).

As stated in the previous section (Heel Strike), the study by Zhou, et al., (2021), outlined how the fatigued gait pattern changes in order to reduce dynamic loading and prevent injuries of the lower limb (Padua, et al., 2006) (Zhou, et al., 2021) (Zhang, et al., 2022). This loading mechanism was outlined to be a compensatory mechanism adopted by active participants who regularly require these systems to promote sports-related performance. The same article goes on to describe that this loading-modification-mechanism enables changes in distal movements thus allowing subtle proximal alterations of movement. As described earlier, the lack of this modification and the lack of regular activity predisposed more significant observations in the sedentary individuals (Zhou, et al., 2021).

Similarly, in the current research (as outlined in: **Table 4.4.5** and **Table 4.4.6**), changes which were observed included: knee flexion and extension; ankle dorsi/plantarflexion; hip ab/adduction; knee ab/adduction; knee rotation; and ankle rotation in the left lower limb. Most of these movements were mirrored by Borotikar, et al., (2008), who associated them with neuro-muscular fatigue. Interestingly, the same authors noted that most significant pre- and post- readings occurred in what they called the "Peak Stance Phase", which constituted 0-50% of the stance phase. The latter 50-100% of the stance phase did not elicit the same differences. In the current research, fatigue-induced increases in knee abduction and internal rotation during the "Peak Stance Phase" (**Table 4.4.6**) were similar to previous observations by Voloshin, et al., (1998), McLean, et al., (2007), Zhou, et al., (2021), and Zhang, et al., (2022), who state that, when exercising at or near exhaustion, their participants registered a reduction in muscle power, making the cartilage and ligaments more vulnerable to excess dynamic loading. This was also apparent when observing the knee rotation changes of both the active and sedentary participants in the current study.

Another significant change in kinematics, which was extensively documented in the available literature, was the relationship between knee abduction/adduction and hip rotation where the increases in knee abduction postures were attributed to the concomitant increase in hip rotation (Wang, et al., 2012). The same observations were noted in the current research.

The significant change in ankle rotation between pre- and post- readings pose an interesting element as the literature is far from clear on the reliability of this data due to extreme variations in the human foot's morphology. Surely, alterations in the discrepancies at the talo-crural axis merit their own research. Ankle supination and pronation deserve to be mentioned within the compensatory mechanism context which was outlined earlier (McLean, et al., 2007). Lastly, ankle rotation, within the context of the current research, was given special consideration in view of the participants' choice of exertion. Sedentary participants were more inclined to partake in fast-walking exertion than their active counterparts who chose running as their preferred method of exertion. Padua et al., (2006) outlined how a fatiguing task which compromised peroneal contractility would inevitably predispose its participants to achieve fatigue in ankle supination muscles. Thus, the aforementioned fatigue-induced changes in the hip and knee positions may have been altered by concomitant ankle strategies.

5.3.3. Weight-transference

Weight-Transference constitutes the latter 50% of the stance phase. As outlined in the previous section, the most significant changes in pre- and post- readings during stance phase occur in the "Peak Stance Phase", which constituted the first half of the stance phase. The latter half do not elicit the same differences (Wang, et al., 2012). Research literature for this particular phase of gait is limited. The current research found significant readings within this phase of gait and these included changes in: pelvic obliquity; pelvic rotation; ankle dorsi/plantarflexion; and hip rotation (**Table 4.4.7**).

The Active participants' changes (**Table 4.4.8**) were more noticeable than those of their sedentary counterparts (**Table 4.4.9**). The changes involved were in: hip ab/adduction; pelvic rotation; ankle ab/adduction; ankle rotation; ankle dorsi/plantarflexion; and hip rotation.

On the other hand, the sedentary participants' changes were in: pelvic obliquity and hip rotation in the left lower limb; and ankle dorsi/plantarflexion in the right lower limb.

Due to the lack of available research with regards to this phase of gait, similarities can be drawn to the Mid-stance and Toe-off stages of gait. Rather than breaking down the literature in an attempt to validate why certain kinematic and kinetic data varied significantly between pre- and post- readings, this phase presented the opportunity to discuss why the active participants registered more significant changes than their sedentary counterparts. This study concluded that the same compensatory mechanisms outlined in the previous sections were responsible for such a phenomenon, which could be validated by the presence of changes in the ankle dorsi/plantarflexion. This kinematic observation was noted in view of the fact that ankle dorsi/plantarflexion readings indicated a shift in the weight distribution of the foot. It is highly likely that the active participants were more aware of the correct positioning of the foot during gait than their sedentary counterparts (Padua, et al., 2006) (Schmitt, et al., 2013) (Barbieri, et al., 2013) (Zhou, et al., 2021) (Zhang, et al., 2022). That being said, it bears repetition that any active-postural-corrections being performed by the active participants at rest, might have gradually disengaged in view of neuro-muscular fatigue. In other words, the same muscles acting to maintain an appropriate posture during rest had reached fatigue level. Therefore, any active, muscular mechanisms which the active individuals had, were inhibited so that goal-performance could be prioritised (Wang, et al., 2012). In this study, this was observed by the participants' inability to perform an "ideal" weight-transference movement during gait.

On the other hand, the sedentary participants continued to demonstrate changes in obliquity and rotatory movements which were consistent with the previous two phases of gait.

5.3.4. Toe-off

Earlier on it was stated that the lower limb kinematic parameters of gait within heel strike are important factors for joint stability. Nonetheless, the same authors desribe howjoint kinematics at toe-off are important determinants of running performance (Gazendam & Hof, 2007) (Bazuelo-Ruiz, et al., 2018). In the current study, during this final stage of the stance phase, all participants were observed to have had a significant change in: ankle dorsi/plantarflexion, pelvic obliquity and hip ab/adduction of the left lower limb; and hip rotation in the right lower limb. Although the researcher did not note any significant changes in the knees during this phase, the literature with regards to knee kinematics during toe-off is abundant, especially with regards to potential knee injuries such as ACL injuries (Borotikar, et al., 2008). McLean, et al., (2007) found that knee imbalances were closely associated with hip kinematic differences, going as far as to say that these alterations are common postural corrections which individuals assume during dynamic exercise (McLean, et al., 2007).

Interestingly, this phase is the first phase of gait which sees its kinematic and kinetic readings potentially altered by both fatigue and decision-making. These two phenomena co-exist within a sport environment, as athletes adapt to various situations which their respective sport could present. Borotikar, et al., (2008) state that it is highly likely that within this phase of gait, the combined manifestation of these two phenomena concomitantly predispose significant alterations in the biomechanical readings of the lower limb. They explain this further with regards to the increase in the possibility of ACL injury risk (Borotikar, et al., 2008). One must also consider that this might be aggravated since fatigue and reactions compromise both central and peripheral processing mechanisms thus resulting in "poor" movement strategies (Wang, et al., 2012).

Results from the data gathered for the current study show that in this phase of gait, active participants' significant mean scores include: ankle dorsi/plantarflexion, pelvic obliquity, hip ab/adduction, hip rotation and ankle rotation (**Table 4.4.10**). These findings are congruent to the findings of Radzak, et al., (2017), who state that fatigue altered: dorsiflexion, plantarflexion, hip ab/adduction, knee internal rotation excursion, maximum velocity, mean velocity and maximum moment, knee flexion moment during loading response, and all GRF variables. The authors associated the kinematic changes with fatigue-induced stiffness (Noehren, et al., 2007) (Noehren, et al., 2012) (Radzak, et al., 2017). In the present study, both active and sedentary participants demonstrated a significant change in pelvic obliquity, and hip ab/adduction of the left lower limb (**Table 4.4.11** and **Table 4.4.12**). As explained earlier, the lack of significant changes observed when comparing active participants with sedentary participants, might reside in the fact that active participants are more used to actively alter their gait to compensate for fatigue and to adapt to their respective sports.

5.3.5. Mid-Swing

In this final phase of gait it was found that all participants demonstrated a significant change in: hip flexion/extension, ankle dorsi/plantar flexion, hip ab/adduction, and knee ab/adduction in both lower limbs (**Table 4.4.13**). These readings constitute the majority of the kinematic readings' alterations found in the active population. Further kinematic readings which were noted within the separate groups included: pelvic rotation for active participants (**Table 4.4.14**); and pelvic tilt, and pelvic obliquity for the sedentary participants (**Table 4.4.15**). Again, literature in this instance of gait is very limited, but if one were to take into consideration the previous bodies of literature, a trend of kinematic alterations that are similar to the stages of gait noted in this study would emerge, such as:

- The combined manifestation of fatigue and decision-making alterations of the active participant;
- Kinematic changes to fatigue-induced stiffness;
- The trend towards increased "net" lower-limb asymmetry following fatigue;
- Extreme variations in the human foot's morphology;
- Increased knee joint laxity, possibly compromising ligament mechanoreceptor feedback and hence, muscle contributions to out-of-plane knee joint stability;
- Compensatory mechanisms of the limb in mid-swing to reduce dynamic loading and preventing injuries of the contra-lateral limb.

The discussion about kinematic and kinetic readings thus comes full-circle as the same components from the previous sections re-appears and exert an effect on the performance of the swing-phase readings during gait. During various sections of the gait cycle, general insights were made about how certain fatigue-induced mechanisms had an effect on the spatio-temporal parameters of gait. The following section will delve into these parameters and provide in-depth analyses of the findings achieved, whilst also consulting the available literature to strengthen the presented arguments.

5.4. Section B: Test Measures

5.4.1. Spatio-Temporal Readings pre- and post-

This section takes a look at the changes noted in the spatio-temporal parameters of all the participants. Interestingly, both active and sedentary participants demonstrated the same changes. The changes observed were in cadence, step time and stride time.

The spatio-temporal data collected for cadence demonstrated an increase in number of steps per minute once participants were fatigued. **Table 4.5.1.** above demonstrates this by stating that the cadence changed from 106 steps per minute to 110 (active: 109; sedentary: 112). This increase in 4 steps per minute can also be observed in the box-plot and the frequency distribution curve of **Diagram 4.0.**. Both diagrams indicate that the mean increase in step frequency was that of 4.21 steps/minute. These findings correlate with numerous studies which demonstrate that upon fatigue the frequency of steps per minute increases. Such studies include the ones by (Gerlach, et al., 2005), (Hunter & Smith, 2007) (Morin, et al., 2011).

The results demonstrated a significant reduction in both the step time and stride time when participants were fatigued. This co-incides with an increase in step frequency, as fatigued participants took more steps and strides within the same period of time. Thus the length of Step and Stride Time in the fatigued individuals reduced when compared to their own non-fatigued performance. Barbieri, et al., (2013), note that in their population of young and older adults, the younger population demonstrated reductions in gait speed and stride length, implying that they adopted a more “conservative strategy” to deal with fatigue. The authors explain that other studies with similar young participants, demonstrated the same strategy. This was explained as a safety measure to reduce risk of injuries (Barbieri, et al., 2013). The article by Morin, et al., (2011), is similar in research design to this current study, and they outline an increase in "contact time" of their fatigued participants (Morin, et al., 2011).

Walking speed was the only significant parameter when observing the effects of fatigue on the entire population sample. Individually, active and sedentary participants did not demonstrate any significant change in walking speed, as presented in **Table 4.5.1.**. In an earlier section we discussed how the study by Radzak, et al., (2017) outlines that fatigue altered the gait kinematics during toe-off. The same study describes how these alterations diminished the maximum velocity, mean velocity and maximum moment of the participant during gait. Yoshino, et al., (2004) too noted a decrease in gait speed. They also remarked on a higher stride-to-stride variability and a noticeable difference in local dynamic stability (Yoshino, et al., 2004). Contrastingly, Barbieri, et al., (2013) outline in their appraisal of the available literature, that the most researched parameters (gait speed, step or stride length and stride time) were not often affected by fatigue. They explain that the parameters which did change with fatigue were reported in only a handful of studies. The same authors agree with some of the observations made in the current research, that the effects of fatigue are dependent on the muscles which were fatigued. They represent this information *vis-à-vis* spatio-temporal parameters and also noted that trunk muscles fatigue yielded poorer results than lower limb muscle fatigue (Barbieri, et al., 2013)**.**

Walking Speed could also have been affected by the phenomena observed during weight-transference and toe-off. As stated earlier, there was a reduction in ankle dorsi/plantarflexion associated with fatigue in postural-correction muscles. It was discussed that habitual muscular mechanisms were inhibited so that goal-performance could be prioritised (Wang, et al., 2012). This led to alterations in the Ground-Reaction Force readings which were noted throughout the stance phase of the fatigued participants. These alterations predisposed an increase in ground-contact during gait, which in turn reduced the speed with which the participants mobilised.

5.4.2. Heart Rate

Heart Rate is one of the most recognised and utilised measures of exercise intensity. It came as no surprise that the difference in mean HR scores pre- and post- for both active and sedentary participants, were significant. **Table 4.5.4.** shows a p value of <0.001. Numerous articles confirm this statement, these include studies by Tulppo, et al., (1996), Plews et al., (2013), and Schmitt, et al., (2013). Within their respective research, these authors established that heart-rate monitoring is an efficient way of evaluating the activity of the autonomous nervous system, as well as the level of exertion of an activity (Tulppo, et al., 1996) (Plews, et al., 2013). Each research evaluated the heart rate variability (HRV) (Schmitt, et al., 2013) and, in the case of Plews et al., (2013), the Resting Heart Rate (RHR). The above studies validated HRV monitoring as an effective means of assessing exercise exertion intensities in patients suffering from cardiovascular conditions. Each study described the increments of HR values during dynamic exercise such as running, as a combination of three different physiological mechanisms:

1. The Frank-Starling law of the heart: refers to the increase in blood volume in the left ventricle. This in-flow of blood stretches the myocytes (cardiac muscles). This causes a more powerful systolic contraction. According to the force generated from such a phenomenon is dependent on exercise intensity.
2. Hormonal factors which include the neuro-hormone catecholamines which are known to increase blood pressure and increase HR.
3. The autonomic nervous system (ANS): alterations to the ANS could involve vagal withdrawal and/or enhanced sympathetic functions (Tulppo, et al., 1996) (Wang et al. 2002) (Perini & Veicsteinas, 2003) (Li, et al., 2005) (Schmitt, et al., 2013). The monitoring of the HRV provides "an indirect evaluation" of the cardiovascular system being affected by the autonomic nervous system. all absolute HRV variables (TP, LF and HF spectral powers) are mainly under vagal modulation and are lowered, a lessened vagal modulation of heart activity is most likely when fatigued (Schmitt, et al., 2013).

5.4.3. Relationships of measures with RPE

The following section delves into the relationships of the objective measures *vis-à-vis* the RPE scores. These measures are a reflection of the participants' progress during the examination aspect of the data collection session. HR, SPO_2 and Speed were correlated against RPE scores utilising the One-Way Anova test.

5.4.3.1. RPE Vs HR

Upon examination of the relationship between RPE and HR scores of all the participants, the p-value extracted from this correlation was that of less than the 0.05 criterion ($p < 0.001$) as seen in **Table 4.5.4.1.**. Therefore the relationship between the two measures was found to be significant. The same p-value was extracted from both the sedentary and the active participants. As explained in the results section, this relationship reflects the fact that on average, the mean heart rate is increasing with every increase in RPE score. This was further supported by the various Pearson correlation tests conducted. Each regression line had a gradient of approximately 4 units **(Diagram 4.1.)**, where it indicates that for every 1 unit increase in RPE, the heart rate is expected to increase by approximately 4 units.

The results obtained in this research correlate with results of other researchers in this field. Research on this relationship is plentiful. Yamashita, et al., (2006) outline in their study how RPE has significant relationships with numerous physiological phenomena such as HR, physical intensity, and physiological intensity (blood lactate levels). Chen, et al., (2013), also explored this relationship, stating that statistically significant differences between the HR and RPE means were observed in their population of Taiwanese men. The authors supported their results with other studies, thus validating their own results (Chen, et al., 2013). Ciolac, et al., (2015), concurred with these statements, as their data analysis showed no significant differences in HR response between high intensity training sessions regulated by HR or RPE scores. They concluded that the RPE scale is a simple, effective and inexpensive tool for prescribing and self-regulating HIT in young subjects (Ciolac, et al., 2015). Chen, et al., (2013), explained how various exercise intensities altered the p-value. This led the authors to state that RPE scores within the Borg RPE 6–20 scale vary according to exercise (Chen, et al., 2013). Similarly, the purpose of the study by Scantlebury, et al., (2017), was to quantify this same relationship within young athletes, by assessing their training loads and the sport's influence on said relationship. Interestingly, the researchers found that this relationship varied within sports. They outlined how, even though blood lactate monitoring is not the most efficient and time-friendly system, the relationship between RPE and HR-and-Blood-lactate-levels yielded more valid results than a simple RPE vs HR (Scantlebury, et al., 2017).

Furthermore, Chen, et al., (2013), also outlined how their regression equation obtained between 11 and 16 RPE scores, varied from the pre-established standard equation stipulated by Borg by an average of 20 to 26 beats per minute. This subsequently shifted the entire scale to a deviation of 20 to 30 bpm. Similar observations were noted in the research conducted by Pollock (1988), with only slight differences noted in the predicted HR values (Chen, et al., 2013). During the data collection of the current research this phenomenon was observed. When the participants were asked to rate their perceived exertion during the treadmill exercise, it was noted that the participants were more familiar with the polar ends of the scale where perceived exertion was either too low or too high. Participants found it harder to rate moderate-intensity exercise (refer to **Diagram 4.1.**).

5.4.3.2. SPO_2 vs RPE

The next RPE relationship which was to be derived from the results gathered in this study, was the SPO_2 -RPE relationship. Again, the One Way ANOVA test was used to compare mean SPO_2 readings between different RPE scores. Much like in the previous relationships all of the participants yielded a statistically significant negative relationship with a p-value of less than 0.05 (All and Active: < 0.01; Sedentary: < 0.015). This resulted in the confirmation of the alternative hypothesis which specified that a relationship was indeed present. From the scatter plots developed (**Diagram 4.5**, and **Diagram 4.6.**), it was observed, that for every 1 unit increase in RPE, the SPO_2 for all the participants was expected to decrease by approximately 0.07 units. The same results varied slightly upon the separation of active and sedentary individuals, with a reduction of approximately 0.1 units for active individuals; and a reduction of approximately 0.10 units per every 1 unit increment in RPE for sedentary individuals.

Literature outlining the relationship between SPO_2 and RPE scores is limited. Meyer, et al., (2004), state that this limitation in the research also arises from the fact that many researchers have not correctly detected their participants' ventilatory threshold in view of inadequate test protocols by which the respiratory compensation point (RCP) is often picked up. The Respiratory Compensation Point (RCP) is the instance whereby hyperventilation takes place, which in physiological terms marks the body's inability to maintain the blood's 7.4 pH value. As exercise intensity increases, so does the rate of lactate production. Eventually this metabolic acidosis leads to a decline in blood pH which stimulates the body to hyperventilate in an attempt to compensate for this phenomenon (Meyer, et al., 2004). Stringer, et al., (1994), state in their research that if an exercise is performed to the point of inducing lactic acidosis, oxygen uptake is initially maintained for a short period of time, promoting a Bohr effect. During lactate acidosis, oxygen concentration in the blood (PO_2) is reduced and CO_2 is released in the circulatory system, thus "forcing" oxygen release from the haemoglobin. This in turn results in muscles not obtaining substantial amounts of oxygen, leading to fatigue and eventually contraction failure. Furthermore, low values of PO_2 will not meet the demand to adequately transport oxygen and the diffusion between the red blood cells and the active sarcoplasm does not occur, inducing further lactate development within the exercising muscle. Another physiological phenomenon between HCO_3- and lactic acid occurs which further acidify the blood (Stringer, et al., 1994). Considering this physiology, one can safely deduce that there exists a relationship between oxygen values and fatigue.

More authors have researched the relationship between RPE-controlled training and its cardiovascular effect on the athlete. Lee, et al., (1995) for instance outline how regular aerobic exercise and intentional physical activity reduces the risk of cardiovascular disease. Ciolac, et al., (2015), analysed and confirmed the usefulness of the 6-20 RPE scale as an objective measure to ensure safety during high intensity training in young sedentary individuals. The findings of Ciolac, et al., (2015), are congruent with the ones observed in this research.

5.4.3.3. Speed vs RPE

Lastly, the final RPE relationship to be examined is between Speed and RPE scores (**Table 4.5.4.4.**). The One Way ANOVA test was implemented and again the alternative hypothesis was accepted as the p-value was less than the 0.05 criterion ($p < 0.001$). The same p value score was derived from both the active and sedentary population, thus this study found a significant positive relationship between speed and RPE (**Diagram 4.3.**). The gradient of the regression line from the generated scatter plot indicated that for every 1 unit increase in RPE, the speed scores increased by an increment of approximately 0.12 units. When separating active and sedentary scores, active participants had an increment of approximately 0.14 units whilst the sedentary had a lower rate of 0.09 units (**Diagram 4.4.**). To put it simply, the faster the participants were running/walking, the higher was their perceived exertion of that exercise.

The previous section delved into the relationship between SPO_2 and RPE, describing how exercise performed to the point of inducing lactic acidosis, will inhibit the exercising muscles from receiving substantial amounts of oxygen, thus leading to fatigue and eventually contraction failure

(Stringer, et al., 1994) (Halson, 2014) (Karvekar, 2019). Whether contraction failure is achieved or not, the force and power generated by the exercising muscle will be reduced, in turn reducing said muscle's efficiency and power. For the lower limbs, this will influence proprioception and speed (Stringer, et al., 1994) (Wang, et al., 2012) (Barbieri, et al., 2013) (Radzak, et al., 2017), demonstrating a relationship between muscle contraction and fatigue.

As stated earlier, Ciolac, et al., (2015) were more interested on the training regimen potential that RPE and speed have in congruence. Their research states that the RPE can help quantify performance and prescribe exercise intensity. When one considers the observations by Ciolac, et al., (2015), in unison with the current study, the positive relationship between RPE and Speed scores would help monitor the athletes' perceived intensity of said exercise, whilst also providing a powerful, simple and cost-effective assessment tool for the trainer/practitioner.

5.5. Summary: Active vs Sedentary

The following section discusses the differences within the rate of change of kinematic and kinetic data between active and sedentary individuals (see section: Active vs Sedentary in the Results chapter). Initially, the score difference was computed for all movements of each participant by subtracting the pre-score from the post-score. Then an Independent Samples T-test was used to compare the mean score differences between two groups of participants. Thus it was possible to evaluate which change in kinematic and kinetic data varied mostly between active and sedentary participants. Sedentary and Active participants' rate of change varied as follows:

- **Changes in Heel-strike**: Ankle Ab/Adduction (**Table 4.6.1**)
- **Changes in Mid-stance**: Knee Flexion/Extension; Ankle Dorsi/Plantar Flexion; Hip Ab/Adduction; Knee Ab/Adduction (right); Ankle Ab/Adduction; Hip Rotation; Knee Rotation; Ankle Rotation (left) (**Table 4.6.2**)
- **Changes in Weight-transference**: Hip Rotation (**Table 4.6.3**)
- **Changes in Mid-swing**: Pelvic Tilt; Pelvic Obliquity (**Table 4.6.5**)

An in-depth evaluation of the kinematic differences has already been carried out in Section A, whereby most of the differences between kinematic and kinetic measures arose from:

- Fatigue-encumbered decision-making alterations within the active participant
- Fatigue-induced lower limb stiffness
- Lower-limb asymmetry following fatigue

- Human Foot's Morphology
- Joint Laxity
- Compensatory mechanisms
- Injuries-Prevention mechanisms

These observations shed light on the major kinematic differences induced by fatigue during the gait of sedentary and active participants. One might speculate that these are the major kinematic differences to be expected from athletes and prospective trainees as they progress from sedentary to active individuals. Along the same lines, Barbieri, et al., (2013), deduced that fatigue was directly proportional to muscle strength, proprioceptive acuity, and delayed neuromuscular responses. The main differences between active and sedentary individuals are indeed the aforementioned phenomena which are able to work concomitantly. The authors go on to explain that fatigue and the phenomena simultaneously predispose an individual's risk of injury during gait or exercise. They associated the increased heel contact velocity and the increase in variability of stride length with this increased risk of falling. Increased step width, reduced gait speed and reduced stride length were associated with compensatory adaptations to reduce the risk of injury (Barbieri, et al., 2013).

There appears to be no other literature that quantifies the kinematic repercussions of fatigue whilst also comparing the sedentary against active measures, surely warranting further research.

5.6. Asymmetry between Left and Right

The kinematic and kinetic data collected within this research was presented with the information of gathered either from the left lower-limb or the right. In one single capture, the Vicon system rendered the movements of one complete cycle for each lower limb. Unfortunately, upon the evaluation of the data gathered, this information was discarded and a more holistic view was taken in the current research's interpretations. That being said, this field certainly merits further research, as numerous other researchers have stated that fatigue exacerbates the presence of asymmetry (Zifchock, et al., 2008). Brown et al. (2014), conducted such a research in an attempt to evaluate whether limb dominance had any effects on the kinematics of the fatigued limb. They did not find any differences, thus concluding that both lower limbs fatigue at a steady and equal rate unbiased by limb dominance (Brown, et al., 2014). Radzak, et al., (2017), on the other-hand stated otherwise. Radzak, et al., (2017), were able to gather data which demonstrated a significant difference in the symmetry angles of various kinematic data of the lower limb. They explained that a grievous limitation of their study is that limb dominance was not collected for all of the individuals but the ones who reported dominant limbs presented interesting data (Radzak, et al., 2017).

5.7. Conclusion

In the current study, the researcher aimed to assess the kinematic and kinetic variations in gait brought about by gait-induced fatigue. In simple terms, muscle fatigue represents a reduction in the ability to generate force or power (Gandevia, 2001). This concept is distinctly different from exhaustion, which is an inability to sustain exercise at predefined target intensities (Vollestad, 1997). Many of the participants in the current research opted to set a numerical value to the speed by which they were walking/running and did not choose to alter that value. Thus, participants chose a speed and kept walking/running for the entire longevity of the exercise. Considering the nature of our cumulative fatiguing task, it is therefore plausible to say that while subjects currently experienced maximal exhaustion, they may not have progressed through to maximal fatigue. Nevertheless, the readings obtained within this study could be described as a "fatigued/exhaustive state". According to Borotikar, et al., (2008), this state is synonymous with the state athletes achieve during exertion. Bazuelo-Ruiz, et al., (2018), observed that this state is associated with neural or neuromuscular fatigue which enables exercise performance to be regulated and monitored by RPE. As discussed earlier, The RPE is a powerful, safe, simple and cost-effective assessment tool (Hampson et al., 2001) (Chen, et al., 2013) (Ciolac, et al., 2015) (Bazuelo-Ruiz, et al., 2018). The current research also concludes that fatigue had a significant relationship with HR, SPO_2, kinematic angles, kinetic forces, and spatiotemporal parameters of gait. Most noticeably, this research observed a significant reduction in ankle dorsi/plantarflexion, as well as a reduction in GRFZ. These observations were evident in Tables 4.4.1, 4.4.2, 4.4.4, 4.4.5, 4.4.6, 4.4.7, 4.4.8, 4.4.9, 4.4.10, 4.4.11, 4.4.13, and 4.4.14. These observations were considered simultaneously as a variance in ankle dorsi/plantarflexion, with inevitable result in a variance in the GRFZ (and vice versa). The relevance of this effect of fatigue on gait can have detrimental effects on active individuals, sedentary individuals, athletes, and the elderly. Various functional, daily activities may be sabotaged and the risk of injury increases.

Chapter 6: Strengths, Limitations, Recommendations for the Future

6.1. Strengths

This research has a number of noteworthy characteristics that contribute to its reliability and significance. The study design is comprehensive and includes multiple measures to guarantee the validity and dependability of the results. The researcher used various established statistical analysis techniques to analyse the data collected, thereby enhancing the accuracy of the findings. Collectively, these characteristics provided a solid foundation for the research study and indicate that the findings are reliable and significant.

Hereafter are various characteristics and actions which enhanced and strengthened the current study:

- **Method strength:** Approach selected. With the current study being both experimental and correlational, numerous benefits were observed. The experimental nature allowed for the research phenomenon to be observed and recreated in a safe environment. The correlational aspect enhanced the data gathered from the experimental procedure and permitted the evaluation of correlations and relationships between the variables. This provided a deeper understanding of fatigue and thus provided a more holistic view into the subject.
- **Method strength: Own Control readings.** In the current study, participants acted as their own control. Readings collected from before the intervention acted as comparative data to the post-intervention readings. This allowed for fewer sources of error as marker placement was maintained between readings. This leads to the next strength.
- **Method strength: Single session.** Having participants partake in only one session rather than multiple ones presents its own benefits both from the researcher's perspective as well as the participants'. The fact that participants partook in only one session, prevented the likelihood of absenteeism.
- **Method strength:** Time allocated for introduction. This was considered important to create a comfortable environment for the participants to feel at ease especially due to the fact that the session might have felt like a physical examination session.
- **Method strength:** Constant temperature within lab. It was deemed crucial to maintain a constant laboratory temperature of 25^{o}C. One had to consider the sensitivity of infrared cameras to thermal changes and also the participants' homeostatic control

and perceived comfort, for the consistency of the data being collected.

- **Method strength:** Removal of excess data. As outlined previously, the captures collected were cropped to cancel out data pertaining to the acceleration or deceleration phase of gait. Only the data at the central 4 metres of the 8 metre walkway were maintained. Gait captured here was at constant velocity.
- **Method strength:** The use of two established measures of fatigue. In the current research RPE and HR monitoring were used simultaneously to establish and determine the level of exertion the participants reached at various stages of the treadmill experimental procedure. As has been already established within the literature review section of this research, both RPE and HR monitoring have been credited as being cost-effective, reliable and repeatable fatigue assessment tools within their own right.

6.2. Limitations

This section identified and discusses the potential weaknesses or limitations of the study, acknowledging any shortcomings and highlighting areas where the study may have been improved. Furthermore, confounding/extraordinary factors have also been included as they have had an effect on the data collection process. The section concludes by providing suggestions how future research may overcome the limitations identified in the study. This was done by proposing modifications to the study design or methods, identifying areas where further research is needed, and suggesting ways of controlling potential sources of bias or confounding factors.

Thus, in spite of the researcher's and the supervisors' best attempts, some limitations were present, and will be listed along with how they affected the research:

- **Time period allocated for the entire research project**. As has been outlined in the aforementioned sections of this chapter, this study has a very intricate nature mainly due to its population size as well as the detail this study delves into. Although 40 participants are more than enough to have a valid study, more correlations could have been extracted from the collected data. Although most of the fundamental topics have been tackled in the current study, they merit further investigation.
- **Method limitation: Time allocated for introduction**. While initially identified as a strength, this aspect also posed certain limitations. Participants, including those with medical

expertise, occasionally struggled to fully understand the nature of the study. Consequently, a significant amount of time was devoted to providing comprehensive explanations within a restricted timeframe.

- **Method limitation: Limb dominance recording**. A limitation of the current study was that lower limb dominance was not recorded. The data collected demonstrated variations between limbs with some readings being represented in only one limb rather than both By incorporating limb dominance recording, a more comprehensive exploration of the reasons behind specific changes occurring in one limb while not in the other could have been conducted in greater depth.

- **Method limitation: Overload periods.** Although the periodical assessment of fatigue during the treadmill exercise could be seen as a methodological strength, as it provided the researcher with numerical representation of the progress of fatigue, some studies such as the one conducted by Schmitt, et al., (2013), stated that this methodology might conversely introduce an overload period. This means that participants might have felt pressured to push themselves to achieve that "one-minute marker" whereby HR and RPE readings were being evaluated, or to withdraw from exercising more in view of certain personal uncertainties that made them believe that they could not achieve said minute-marker. This was mitigated by informing the participants that no such markers were in place and that they could stop at any given time regardless of the minute-markers.

- **Method limitation: Rapid deterioration in fatigue.** Borotikar, et al., (2008), and McLean, et al., (2007), state that within a "pre-test–fatigue – post-test model", a rapid recovery from fatigue was noticed immediately after the fatiguing exercise was concluded. The authors outline how this system may compromise outcome and conclusion efficacies (McLean, et al., 2007) (Borotikar, et al., 2008). The current study's research design is "pre-test–fatigue – post-test model", and although participants were instructed to walk on the walkway immediately upon reaching fatigue, this system may not cancel out all related sources of error.

- **Apparatus limitation: Treadmill.** Although used effectively and throughout the entire research, the available treadmill within the Clinical Biomechanics Laboratory had a few limitations. The treadmill display did not illustrate detailed measurements of speed and distance covered; for instancenumerical data collected from the treadmill was demonstrated as a single decimal value. This reduced the accuracy of the readings gathered.

○ **Apparatus limitation: Force plates size.** The AMTI force plates within the Clinical Biomechanics Laboratory at the University of Malta, Mater Dei Hospital, have 50x50cm dimensions and are placed in close proximity to one another. Many of the participants were missing the mark on hitting the force plates due to their long stride length. Therefore, more walks had to be performed to capture the three bilateral force-plate landings required. Furthermore, the force plates are visible which may have created a bias during gait as participants could have altered their gait to land a hit.

○ **External Limitation: Examination periods**: Data collection was hindered twice because of examination periods at the University of Malta. Participant recruitment was low and therefore the study was temporarily on hiatus.

○ **External Limitation: COVID-19.** Numerous stages within the methodological process were influenced by the **COVID-19** pandemic. These resulted in set-backs which were difficult to counteract. Prospective subjects were cautious and reticent to participate in the current study.

○ **Population Limitation**: Active > Sedentary. As stated earlier, a convenience and a referral sampling approach was utilised in this study for the recruitment of participants. As the Registrar disseminated the current research via its university portal, interested candidates (who met inclusion criteria for the study), were predominantly more active than sedentary. This could be associated with many factors. Wanner, et al., (2006), suggest that the reason for this phenomenon may be that active individuals are more interested in health-related research and more motivated to participate in studies that promote physical activity. They also propose that sedentary individuals may be less likely to engage in physical activity interventions due to a perceived lack of confidence in their ability to be physically active (Wanner, et al., 2006).

6.3. Recommendations for the Future

Use of GRFV: The ground reaction forces X, Y, and Z have been collected and interpreted within the current research as they represented the kinetic data that the participants exerted on the force-plates during gait. A more accurate representation of the kinetic data would have been illustrated by the Ground Reaction Force Vector (GRFV). Being a vector, GRFV is a three-dimensional quantity that represents the net force and moment occurring during ground contact. The following are reasons supporting the validity of GRFV:

- More comprehensive: provides one reading rather than three (GRF X, Y, and Z),
- More accurate representation: The GRFV is a vector quantity, meaning it has both magnitude and direction.
- Better analysis: especially in the measurement of joint moments and powers (Zatsiorsky, 2002).

GRFV was not implemented in this dissertation as most of the available research collected utilized the GRFX, Y, Z system. This is the default system provided by Vicon and other Kinetic assessment tools available at the Clinical Biomechanics Laboratory at the University of Malta.

Identification of Location of Fatigue: Although the current research explains the kinematic and kinetic differences pre- and post-exertion, the exact location of fatigue could not be surmised. This research focused on the specific movement deficits elicited by fatigue. In a future study EMGs on various muscle groups could be implemented for the assessment of fatigue on a muscular level. EMG readings would permit the researcher to precisely locate the site of fatigue, and also to distinguish and differentiate between the different types of fatigue which could be influencing the participants such as cardiovascular, psychological, etc.

Limb Dominance Analysis: As stated within the limitations section of the current study, the exploration of the impact posed by limb dominance on the fatigued gait was not studied. A future study could examine whether individuals exhibit different gait adaptations in their dominant versus non-dominant limbs under conditions of maximal fatigue. This analysis could help provide insights into how asymmetry in limb function affects gait biomechanics whilst also delving into the implications for injury prevention and rehabilitation strategies.

Gender-Specific Analysis: The current study observed the biomechanical effects of fatigue on an individual level. Participants acted as their own control, thus permitting a more holistic and varied population sample of young adults. This research could be further extended to investigate how gender influences fatigue-induced changes in gait parameters. Such research could assess whether there are gender-specific differences in gait parameters during and after exertion, and whether these differences relate to biomechanical variations. Such gender-specific findings could contribute to a more tailored exercise and rehabilitation programs, acknowledging the distinct physiological responses of gender-specific fatigue.

Chapter 7: Conclusion

7.1. Conclusion

The current study aimed to understand the effects of fatigue on gait by adopting a "general fatigue strategy" and numerous statistical results were obtained. Findings include:

a) Fatigue induces significant changes in lower limb kinematic and kinetic readings;
b) Fatigue-induced changes vary between active and sedentary individuals;
c) An active lifestyle permits the development of compensatory mechanisms which reduce injuries that arise from various stages of the gait cycle (such as stress fractures during heel strike, and ACL injuries during weight-transference and toe-off);
d) Fatigue coincides with changes in the spatiotemporal parameters of gait;
e) The effects of fatigue on the spatiotemporal gait parameters are dependent on the muscles that are fatigued.

Most noticeably, this research observed a significant reduction in ankle dorsi/plantarflexion, as well as a reduction in GRFZ. These particular kinematic and kinetic data were considered simultaneously, as any variation in ankle dorsi/plantarflexion will inevitably result in a variation in the GRFZ (and vice versa). This effect of fatigue on gait can have detrimental effects on athletes, the elderly, and the general population. Functional, daily activities may be sabotaged and the risk of injury increases.

For active individuals, ankle dorsi/plantarflexion and GRFZ are crucial movements and forces as they permit foot clearance, and propulsion during the swing phase of gait. Reduced ankle dorsiflexion can lead to reduced stride lengths and running speeds. Reduced ankle mobility can causes athletes to change their running mechanics, which can negatively impact performance and increase the risk of injuries (e.g., Achilles tendinitis, plantar fasciitis) (Macrum, et al., 2012). Furthermore, dorsi/plantarflexion play a pivotal role in shock-absorbing activities upon landing, which also increases the risk of ankle sprains and other lower limb injuries (Baellow, et al., 2020).

Similarly, these kinematic and kinetic changes in gait can have a precarious effect on the sedentary individuals as well as the elderly. Altered gait patterns in the elderly are closely associated with increased risk of falling. Physiologically, the elderly undergo changes in ankle range of motion (ROM), muscle strength, muscle bulk, and proprioception. Lord & Sturnieks, (2005), observe that these phenomena can lead to poor biomechanical control of the lower limbs, thus often resulting in a shuffle-like gait pattern and reduced step length. These increase the risk of tripping/falling (Lord & Sturnieks, 2005). Poor environment management and lack of training often predispose reduced balance control and compromised stability during gait, further heightening fall risk (Nnodim & Yung, 2015).

The general population and workers who have physically demanding occupations, much like active individuals, often rely on optimal ankle dorsiflexion, plantarflexion, and GRFZ to maintain efficiency during the work-place environment. Reduced ankle mobility hinder squatting, bending, and climbing movements, which if left unresolved predispose WMSDs (such as lower back pain, knee strains, and ankle sprains). Physically demanding occupations who require shock-absorption mechanisms may lead to a reduction in the effective distribution of forces at the ankle and thus potentially contribute to overuse injuries (Mattock, et al., 2021).

In conclusion, this research observed significant effect of fatigue on ankle kinematic and kinetic mechanisms. Ankle dorsi/plantarflexion, GRFZ, along with other (less-prevalent) biomechanical alterations led to significant reduction in cadence, step times and stride times. It was also discussed how these kinematic and kinetic paradigms have substantial implications for the gait pattern of athletes, the elderly, and the general population. The researcher agrees with the literature that more research needs to be carried out to observe this phenomenon. Further evaluation of the kinematic and kinetic effects of fatigue could delve deeper into the subjects' age and the exercises selected by the participants. As stated earlier, the current study allowed the participants to adopt an exercise on the treadmill as they deemed fit. Within the current research, whether the patient chose to walk, fast-walk, bisque-walk, jog or run was irrelevant as all the data ended up being processed and grouped as "Exertion". The literature states that different muscles are involved in different types of walking, and thus the exercise-induced fatigue is not relevant to every participant.

This study highlights the biomechanical effects of fatigue on gait, the efficiency and reliability of the RPE scale as an assessment tool, and an understanding of the physical representations of fatigue within our clinical practice.

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APPENDIX

Appendix 1: Forms

- Appendix Form 1.: Participants' Information Sheet Sample
- Appendix Form 2.: Participants' Consent Form Sample
- Appendix Form 3.: Data Sheet Sample
- Appendix Form 4.: Laboratory Premises Approval
- Appendix Form 5.: Approval from Registrar
- Appendix Form 6.: REDP Form: Supervisor Endorsement
- Appendix Form 7.: UREC Form: Approval

Appendix Form 1.: Participants' Information Sheet Sample

Gianluca Pollacco
6, “La Senese”,
Triq l-Arznu
San Gwann,
SGN1751
25/11/2021

Participants` Information Sheet

Dear Sir/Madam,

My name is Gianluca Pollacco and I am a student at the University of Malta, presently reading for an M.Sc. in Clinical Biomechanics. I am presently conducting a research study for my dissertation titled **Biomechanical variations in gait of active and sedentary individuals upon perceived exertion**; this is being supervised by Prof Alfred Gatt, and co-supervised by Mr Darren Sillato. This letter is an invitation to participate in this study. Below you will find information about the study and about what your involvement would entail, should you decide to take part.

The aim of my study is to investigate the effects of fatigue upon biomechanical parameters in the lower limbs in the active adult when compared to the sedentary adult. Your participation in this study would help contribute to a better understanding of the physical effects fatigue on the individual. The information gathered would help the clinician, within the clinical setting, to differentiate between a person’s fatigued walking pattern and normal walking pattern. This research would also interest you as this study will shed light on the differences between an active and a sedentary lifestyle. Any data collected from this research will be used solely for purposes of this study.

Should you choose to participate, you will be asked to attend the Clinical Biomechanics Laboratory at the Faculty of Health Sciences (University of Malta). You will then be asked a series of questions and various personal measurements (such as height and weight) will be collected (refer to: Data sheet). The questions put forward will address your current profession, lifestyle, and sport performance. Following the questions, reflective markers will be placed in strategic locations on your clothing on the lower limbs, and pelvis. You will then be instructed to walk at a self-selected comfortable pace on a walkway whereby your actions will be captured (as numerical mapping co-ordinates) by an 18-camera Vicon Motion Capture system. The cameras in this system do not take actual videos or photographs, but record the movement of the reflective markers to allow us to measure the angles of movement of your joints. After this assessment, the markers are going to be left in place for the duration of a 30-minute (max) exercise programme. The exercise programme will consist of walking/running at a self-selected pace on a treadmill. You are free to pace yourself as you see fit during this exercise session. After the conclusion of the training session, you will kindly be asked to once again walk at a self-selected comfortable pace on the walkway whereby your movements will once again, be captured by an 18-camera Vicon Motion Capture system]. In total it is envisaged that an entire session should take approximately one hour to complete.

Possible risks anticipated from the aforementioned methodology include: falls and injuries, although these are unlikely since the session, as stated before, will be: self-paced, held within a secure environment, and with numerous mitigation protocols in place.

Data collected during the session will be pseudonymised, meaning that personal data will be accessible to myself only and the rest of the data will be given a code number for reference. This data may only be accessed by myself, the researcher. The academic supervisors, Dr Alfred Gatt (Supervisor) and Mr Darren Sillato (Co-supervisor), will typically have access to coded data only. There may also be exceptional circumstances whereby the supervisors and examiners may need to access the personal data for verification purposes. The data files will be stored on the researcher`s personal hard-disc that is password protected and in an encrypted format. Furthermore, the data files will not be sent via email, replicated and/or uploaded in any server, cloud storage, site or any other media. Personally identifiable data, namely the subsequent consent form, will be stored separately from the aforementioned pseudonymised data. Any material in hard-copy form will be placed in a locked cupboard and kept until results are published. Upon completion of the study, all your personal data will be destroyed.

Participation in this study is entirely voluntary; in other words, you are free to accept or refuse to participate, without needing to give a reason. You are also free to withdraw from the study at any time, without needing to provide any explanation and without any negative repercussions for you. Should you choose to withdraw, any data collected will be deleted.

If you choose to participate, please note that there are the following direct benefit to you: a gratuitous gait analysis assessment conducted through the use of cutting-edge technology. Your participation does not entail any known or anticipated risks as the session will be self-paced and within a secure environment.

Please note also that, as a participant, you have the right under the General Data Protection Regulation (GDPR) and national legislation to access, rectify and where applicable ask for the data concerning you to be erased. Once the study is completed and the results are published, the data will be retained in anonymous form. Any personal details will be destroyed.

A copy of this information sheet is being provided for you to keep and for future reference.

Thank you for your time and consideration. Should you be interested in participating in this study, or should you have any questions or concerns do not hesitate to contact me on **+356 798 240 96** or by e-mail **gianluca.pollacco.13@um.edu.mt** or my supervisor Prof. Alfred Gatt on **2340 1153** or via e-mail **alfred.gatt@um.edu.mt.**

Sincerely,

Mr. Gianluca Pollacco

Researcher

Prof. Alfred Gatt

Research Supervisor

Appendix Form 2.: Participants' Consent Form Sample

L-Università ta' Malta

Participants` Consent Form

Biomechanical variations in gait of active and sedentary individuals upon perceived exertion.

I, the undersigned, give my consent to take part in the study conducted by Gianluca Pollacco. This consent form specifies the terms of my participation in this research study.

1. I have been given written and/or verbal information about the purpose of the study; I have had the opportunity to ask questions and any questions that I had were answered fully and to my satisfaction.
2. I also understand that I am free to accept to participate, or to refuse or stop participation at any time without giving any reason and without any penalty. Should I choose to participate, I may choose to decline to answer any questions asked. In the event that I choose to withdraw from the study, any data collected from me will be destroyed.
3. I understand that I have been invited to participate in quantitative, correlational, experimental design study in which the researcher will conduct an assessment to investigate the effects of fatigue upon biomechanical parameters in the lower limbs in the active adult when compared to the sedentary adult. I am aware that the entire assessment will take approximately one hour. I understand that the assessment is to be conducted in a place and at a time that is convenient for me.
4. I am aware that, if I give my consent, I be instructed to walk at a self-selected comfortable pace on a walkway whereby my actions will be captured by an 18-camera Vicon Motion Capture system. These captures will not illustrate my identity but rather show a mapping of the location of the reflective markers during gait. Furthermore, this mapping will be further converted into numerical co-ordinates and tabulated.
5. I understand that no actual video, audio or photographic recordings will be made.
6. I understand that possible risks anticipated from the aforementioned methodology include: falls and injuries, although these are unlikely since the session, as stated before, will be: self-paced, held within a secure environment, and with numerous mitigation protocols in place..
7. I understand that *there are the following direct benefit to me*: a gratuitous gait analysis assessment conducted through the use of cutting-edge technology. I also understand that

this research may benefit others by: providing a better understanding of the effects fatigue can have on the individual and consequently, the safety of the individual. The information gathered would help the clinician, within the clinical setting, to differentiate between a person's fatigued walking pattern and normal walking pattern.

8. I understand that, under the General Data Protection Regulation (GDPR) and national legislation, I have the right to access, rectify, and where applicable, ask for the data concerning me to be erased.
9. I understand that this consent form will be stored in a locked cupboard, separate from the collected pseudonymised data, until the completion of the study. Once the study is completed, all data will be erased.
10. I understand that there may also be exceptional circumstances whereby the supervisors and examiners may need to access the personal data for verification purposes.
11. I understand that all data collected (except the aforementioned consent form) will be stored in an pseudonymised form until completion of the study and following publication of results, all data will be erased.
12. I have been provided with a copy of the information letter and understand that I will also be given a copy of this consent form.

I have read and understood the above statements and agree to participate in this study.

Participant: ______________________________

Signature: ______________________________

Date: ______________________________

Mr. Gianluca Pollacco
Researcher
gianluca.pollacco.13@um.edu.mt

Prof. Alfred Gatt
Research Supervisor
alfred.gatt@um.edu.mt
2340 1153

Appendix Form 3.: Data Sheet Sample

Participant Data Sheet		
Date:	______________________	
Participant Code:	______________________	
Age:	______________________	
Weight:	______________________	
Height:	______________________	
Waist girth:	______________________	
Hip girth:	______________________	
Leg length	______________________	
ASIS distance	______________________	
Knee width	______________________	
Ankle width	______________________	
Occupation level of activity:	Active:	Sedentary:
Lifestyle:	Active:	Not Active:
Sport:	Gym:	Other:
Specify: ____ ____		
How often do you participate in sport/gym/hobby? ______________________		

Time	RPE	HR	SPO_2	Distance	Speed
1 minute:					
2 minute:					
3 minute:					
4 minute:					
5 minute:					
6 minute:					
7 minute:					
8 minute:					
9 minute:					
10 minute:					
11 minute:					
12 minute:					
13 minute:					
14 minute:					
15 minute:					
16 minute:					
17 minute:					
18 minute:					
19 minute:					
20 minute:					
21 minute:					
22 minute:					
23 minute:					
24 minute:					
25 minute:					
26 minute:					
27 minute:					
28 minute:					
29 minute:					
30 minute:					

Vicon Mapping Data

Appendix Form 4.: Laboratory Premises Approval

L-Università ta' Malta

Gianluca Pollacco <gianluca.pollacco.13@um.edu.mt>

Laboratory Premises approval

2 messages

Gianluca Pollacco <gianluca.pollacco.13@um.edu.mt> 15 January 2022 at 09:54
To: Cynthia Formosa <cynthia.formosa@um.edu.mt>
Cc: Gatt Alfred <alfred.gatt@um.edu.mt>, Darren Sillato <sillato@gmail.com>

Dear Prof Formosa,

My name is Gianluca Pollacco, and I am currently reading for an M.Sc. in Clinical Biomechanics at the University of Malta. In fulfilment of the aforementioned course I require permission to conduct a research study entitled "**Biomechanical variations in gait of active and sedentary individuals upon perceived exertion**".

The aim of my study is to investigate the effects of fatigue upon biomechanical parameters in the lower limbs in the active adult when compared to the sedentary adult. Participation of a number of individuals in this study would help contribute to a better understanding of the physical effects of fatigue on the individual. The information gathered would shed light on signs of gait fatigue which the clinician, within the clinical setting, could look out for within his/her practice. This study should shed light on the differences between an active and a sedentary lifestyle. Any data collected from this research will be used solely for the purposes of this study..

In the light of the foregoing, I am hereby requesting your permission to utilise the 18-camera Vicon Motion Capture system as well as the Clinical Biomechanics Laboratory premises at the Faculty of Health Sciences (Mater Dei Hospital) for this research.

Potential participants who agree to take part in this study will be requested to attend the Clinical Biomechanics Laboratory at the Faculty of Health Sciences (University of Malta). The participants will then be asked a series of questions and various personal measurements (such as height and weight) will be collected (refer to: Data sheet). The questions put forward will address their current profession, lifestyle, and sport performance. Following the questions, reflective markers will be placed in strategic locations on the participants' lower limbs, and pelvis. They will then be instructed to walk at a self-selected comfortable pace on a walkway whereby their actions will be captured (as numerical mapping co-ordinates) by an 18-camera Vicon Motion Capture system. After this assessment, the markers are going to be left in place for the duration of a 30-minute (max) exercise programme. The exercise programme will consist of walking/running at a self-selected pace on a treadmill. Participants are free to pace themselves as they see fit during this exercise session. After the conclusion of the training session, the participants will kindly be asked to once again walk at a self-selected comfortable pace on the walkway whereby their movements will once again, be captured by an 18-camera Vicon Motion Capture system. In total it is envisaged that an entire session should take approximately one hour to complete. Data collected during the session will be pseudonymised, meaning that personal data will be accessible to myself only and the rest of the data will be given a code number for reference.

Your support in helping me complete my studies is appreciated.

I am also providing you with copies of my dissertation proposal, information letters and consent forms for your kind perusal.

Should you have any questions or concerns do not hesitate to contact me on +356 798 240 96 or by e-mail gianluca.pollacco.13@um.edu.mt or my supervisor Prof. Alfred Gatt on alfred.gatt@um.edu.mt.

Thank you for your time and consideration.

Yours Sincerely,
Gianluca Pollacco

6 attachments

Registrar approval.pdf
12K

data sheet.pdf
240K

Biomechanical variations in gait of active and sedentary individuals upon perceived exertion.pdf
1427K

intermediary information sheet and letter of consent.pdf
634K

Participant information sheet and letter of consent.pdf
662K

ittra ta informazzjoni u kunsens ghal partecipanti.pdf
713K

Cynthia Formosa <cynthia.formosa@um.edu.mt> 15 January 2022 at 18:52
To: Gianluca Pollacco <gianluca.pollacco.13@um.edu.mt>
Cc: Gatt Alfred <alfred.gatt@um.edu.mt>, Darren Sillato <sillato@gmail.com>

No Objection from my end. You can use the lab for the duration of your data collection.

regards

CF
[Quoted text hidden]

Appendix Form 5.: Approval from Registrar

L-Università
ta' Malta

Office of the Registrar

University of Malta
Msida MSD 2080, Malta

Tel: +356 2340 2385/6
academicregistrar@um.edu.mt

www.um.edu.mt

22 January 2022

Mr Gianluca Pollacco (294695M)
6 La Senese
Triq l-Arznu
San Gwann SGN 1751

I refer to your request for permission to contact students to participate in your research study that you are conducting in connection with the dissertation you will be presenting in partial fulfilment for the degree of Master of Science in Clinical Biomechanics.

The Office of the Registrar is willing to distribute your invitation letter amongst students, subject to the approval of the Faculty Research Ethics Committee.

Dr Colin Borg
Registrar

Appendix Form 6.: REDP Form: Application

L-Università ta' Malta

Research Ethics and Data Protection Form

University of Malta staff, students, or anyone else planning to carry out research under the auspices of the University, must complete this form. The UM may also consider requests for ethics and data protection review by External Applicants.

Ahead of completing this online form, please read carefully the University of Malta Research Code of Practice and the University of Malta Research Ethics Review Procedures. Any breach of the Research Code of Practice or untruthful replies in this form will be considered a serious disciplinary matter. It is advisable to download a full digital version of the form to familiarise yourself with its contents (https://www.um.edu.mt/research/ethics/resources/umdocuments/). You are also advised to refer to the FAQs (https://www.um.edu.mt/research/ethics/faqs).

Part 1: Applicant and Project Details

Applicant Details

Name: Gianluca

Surname: Pollacco

Email: gianluca.pollacco.13@um.edu.mt

Applicant Status: Student

Please indicate if you form part of a Faculty, Institute, School or Centre: * Faculty of Health Sciences

Department: * Podiatry Department

Principal Supervisor's Name: * Prof Alfred Gatt

Principal Supervisor's Email: * alfred.gatt@um.edu.mt

Co-Supervisor's Name: Mr Darren Sillato

Course and Study Unit Code: * Master of Science in Clinical Biomechanics

Student Number: * 294695M

Project Details

Title of Research Project: * Biomechanical variations in gait of active and sedentary individuals upon perceived exertion

Project description, including research question/statement and method, in brief: *

Research Question

What are the kinematic and kinetic manifestations of fatigue in adults with varying levels of daily activity?

Statement of research problem

Following a thorough review of the research, there seems to be insufficient evidence on the effects of fatigue on the gait pattern of university students. Available literature on the effects of fatigue on gait was found to be targeted at specific population groups, be it athletic, elderly or obese individuals. Although very valid within their specific niches, these studies do not address individuals who do not fall in the aforementioned categories. Furthermore, there are contradictory views and conclusions about the manifestations of fatigue on gait within the available literature. This study aims to address these contradictions, by providing a holistic view and a guide to this phenomenon. Within the clinical environment, healthcare providers would benefit from a guide of the physical manifestations of fatigue as this would contribute to an increase in patient safety and confidence within the clinical environment. This study aims to shed light on the effects of fatigue on gait by quantifying and objectifying, in biomechanical terms, the changes in gait after a workout by the healthy individual. This study will help the clinician to differentiate between a person's fatigued gait pattern and normal (unfatigued) one. Employers would benefit from this research as knowledge about fatigue would promote better understanding in the employees' exposure to work-related musculoskeletal conditions. And lastly, this research would also benefit the individual with regards to the different effects of an active or a sedentary lifestyle. The target population are adult individuals without any medical conditions who are currently enrolled as students at the University of Malta. This population sample was selected as students have varying levels of mobility and can be easily reached through the same intermediary (the Registrar at the University of Malta).

Will project involve collection of primary data from human participants? Yes / Unsure

Explain primary data collection from human participants:

a. Salient participant characteristics (min-max participants, age, sex, other): *

Inclusion criteria:

- age range 18-30 years
- ability to mobilise independently
- sedentary cohorts; not attending a gym, classes or participate in organised sporting activity. Sedentary cohorts also include people who have a very low-intensity activity at the workplace.
- physically active cohorts; attending a gym, classes or participate in organised sporting activity. Active cohorts may also include people who have moderate- to high-intensity activity at the workplace.

Exclusion criteria:

- previous history with other peripheral and central neurological conditions
- pre-existing conditions that may alter sensory perception
- history of acute lower limb orthopaedic conditions that could affect the participant's ambulatory performance;
- blindness or severe visual impairments;
- severe cognitive impairment that prohibit participant comprehension during interventions;
- Pathologies of oncological origin;
- Severe cardiorespiratory conditions that may be the primary cause of reduced mobility.

The target population are forty adult individuals without a well-defined medical condition (or an unexplained fatigue syndrome) who are currently enrolled as students at the University of Malta.

b. How will they be recruited: *

This population sample was selected as students have varying levels of mobility and can be easily reached through the same intermediary (the Registrar at the University of Malta). The participants would be thoroughly briefed about the experimental procedures this study would ensue and interested participants will contact me (as the researcher) via mobile phone or email as indicated on the information letter. Signed consent will then be obtained when the participants meets the researcher for data collection.

c. What they will be required to do and for how long: *

Data collection will occur at the Clinical Biomechanics Laboratory at the Faculty of Health Sciences (University of Malta). The experimental readings, tests and outcome measures will all be conducted and collected by myself (the researcher, a registered AHP-Physiotherapist with three years' experience of working within the hospital setting) to ensure inter-tester reliability.

Upon entering the Clinical Biomechanics Laboratory the participants will be asked a series of questions and antropometric data will be collected (refer to Appendix: Data sheet). The questions put forward to the participants will be addressed towards the participants' profession, lifestyle, and sport performance. Personal data will be pseudonymised.

The participants will be assessed at the beginning of the study so that the participants' initial kinetics and kinematics can be measured and tabulated. Upon examination, reflective markers will be placed according to the Plug-in-Gait model (Vicon, UK) across all the joints of the lower limb, trunk, upper limb, neck and head. The participants will then be instructed to walk (with adequate footwear) at a self-selected comfortable pace on a walkway whereby their actions will be captured by an 18-camera Vicon Motion Capture System. This is a validated system utilized both for research and for hospital assessment of gait of patients with neurological gait disorders.

After the initial assessment, the participants will receive a 30 minute (maximum) exercise programme which will consist of walking/running at a self-selected pace on a treadmill. During this period, heart rate and SPO2 parameters will be monitored for safety reasons. Participants will receive individual attention during the treatment sessions to promote safety and confidence during the session. Participants will be free to pace themselves as they see fit during the treatment sessions and will not receive any bias or extra coaxing/motivation for performance. Participants will be instructed to stop the session should HR and SPO2 parameters reach high values (i.e. should SPO2 values dip lower than 92% and HR values rise higher than 120 beats per minute). Furthermore, the session will be stopped whenever the participant says that s/he is fatigued with a score of 17 or higher on the RPE scale. Should the participant feel too fatigued prior to reaching the 17 score on the RPE, the session will also be stopped.

The session itself will take no more than one hour with 30 minutes being dedicated to pre- and post-intervention assessment, and a 30-minute-max period for the intervention.

d. If inducements/rewards/compensation are offered: *

None.

e. How participants/society may benefit: *

Direct benefit (participant): participants will receive knowledge about fatigue and gait.

This research would benefit clinicians like physiotherapists within their clinical practice as it would serve them as a standardised guideline and reference of the effects fatigue can have on the individual and consequently, the safety of the individual. The clinician will be able to differentiate between a person's fatigued walking pattern and normal walking pattern. This research would also benefit the individual with regards to the effects of an active or a sedentary lifestyle.

f. If participants are identifiable at any stage of the research: *

The data obtained from the questions will be pseudonymised.

The data captured by the Vicon Motion Capture System will be a mapping of the infrared-reflection-locations of the markers placed on the participants. Therefore, there will be no live video captures of the individuals and pseudo-anonymity will be maintained, in accordance with GDPR guidelines. Each individual's mapping will also be given a code number instead of any of the participant's particulars. After this assessment, the markers are going to be left in place for the duration of the training programme in order to minimize human errors of marker re-application.

g. The manner in which you will manage and store the data: *

Written consent forms will be filed and kept under lock and key in a secure location in which they will stay until the end of the research or should the participant choose to withdraw from the study. No digital copies of the consent forms will be made nor will they be uploaded to any cloud-servers.

Results will be recorded pseudo-anonymously, and will only illustrate the demographic and the mapping data. All the data collected will be immediately saved onto a password-protected hard-disk in a password-protected folder and accessed on the researcher's personal, password-protected laptop running on Windows 10 using Folder Lock 7.8.4 as an encryption software. The personal data will not be stored in any computer and will not be uploaded to any cloud servers. A backup will be made on a password-protected external hard drive using the same encryption system, which will be kept in a safe under lock and key, to which only the researcher has access. All non-personal information is to remain private until the paper has been published, and only shared with relevant UM supervisors for guidance purposes if necessary. Following the end of the project, all personal data that can identify the subjects will be destroyed.

Part 2: Self Assessment and Relevant Details

Human Participants

1. Risk of harm to participants: Yes / Unsure

The participants eligible for this study are University of Malta students who are able to mobilise independently and have good balance. This reduces the likelihood of falls and injuries from the participants. Then again, the nature of the study is designed in such a way that participants will be free to pace themselves as they see fit during the treatment sessions and will not receive any bias or extra coaxing/motivation for performance. Participants will be instructed to stop the session should HR and SPO2 parameters reach high values. Furthermore, the session will be stopped whenever the participant says that s/he is fatigued with a score of 17 or higher on the RPE scale. Should the participant feel too fatigued prior to reaching the 17 score on the RPE, the session will also be stopped.
Furthermore, should the researcher notice that the participants are fatigued, the participants will be instructed to stop or slow down to ensure safety.

Treadmill walking/jogging: will not contain any risk for the participants as the treadmill is a safe apparatus with easy controls to manage the device. This by itself makes this assessment a very low risk intervention. As stated before, the participants chosen for this study will have a high degree of mobility and balance-control, therefore the likelihood of injuries and accidents during the treatment should be minimal.

Should any emergency arise, the following measures are in place:
- qualified health-care professional (myself, the researcher, a registered AHP-Physiotherapist with four years' experience of working within the hospital setting) present during the session
- venue for data collection is close to the Mater Dei Hospital premises
- session will be conducted within a safe environment
- assessment area is spacious and allows the researcher to aid participants
- treatment session will be conducted on safe apparata
- A hoist is in place to aid the participant should the need arise
- participants are instructed to pace themselves comfortably
- participants will be given individual attention

2. Physical intervention: No / N.A.

3. Vulnerable participants: No / N.A.

4. Identifiable participants: Yes / Unsure

The likelihood that participants' identity might be revealed in my research is minimal. The nature of the data collected are as follows:
- Antropometric data: Age, Weight, Height, Waist girth, Hip girth, ASIS Distance, Leg length, Knee width, and Ankle width.
- Occupation Level of Activity
- Lifestyle Level of Activity
- Mapping Data (Vicon Motion Capture)

The aforementioned data will be inputted in the data sheet (attached). As can be seen in the Data sheet document, each participant will be given a code. Thus the participants' identities will remain anonymous.

All the data collected will be immediately processed onto a results workbook on Excel and the hard-copy version will be destroyed immediately during the data collection session. The data in the Excel workbook would be saved onto a password-protected hard-disk in a password-protected folder and accessed on the researcher's personal, password-protected laptop running on Windows 10 using Folder Lock 7.8.4 as an encryption software. The personal data will not be stored in any computer and will not be uploaded to any cloud servers. A backup will be made on a password-protected external hard drive using the same encryption system, which will be kept safely under lock and key, to which only the researcher has access. All non-personal information is to remain private until the paper has been published, and only shared with relevant UM staff for guidance purposes if necessary. Following the end of the project, all personal data that can identify the subjects will be destroyed.

5. Special Categories of Personal Data (SCPD): Yes / Unsure

SCPD data collected are:
Age, Weight, Height, Waist girth, Hip girth, ASIS Distance, Leg length, Knee width, and Ankle width.

As stated above, all the data collected will be immediately processed onto a results workbook on Excel and the hard-copy version will be destroyed immediately during the data collection session. The data in the Excel workbook would be saved onto a password-protected hard-disk in a password-protected folder and accessed on the researcher's personal, password-protected laptop running on Windows 10 using Folder Lock 7.8.4 as an encryption software. The personal data will not be stored in any computer and will not be uploaded to any cloud servers. A backup will be made on a password-protected external hard drive using the same encryption system, which will be kept safely under lock and key, to which only the researcher has access. All non-personal information is to remain private until the paper has been published, and only shared with relevant UM staff for guidance purposes if necessary. Following the end of the project, all personal data that can identify the subjects will be destroyed.

6. Human tissue/samples: No / N.A.

7. Withheld info assent/consent: No / N.A.

8. 'opt-out' recruitment: No / N.A.

9. Deception in data generation: No / N.A.

10. Incidental findings: Yes / Unsure

Incidental findings might include altered gait patterns in view of various pathological conditions or habitual gait patterns. Should these findings arise, the participants will be informed and encouraged to contact their family doctors.

Unpublished secondary data

11. Human: No / N.A.

12. Animal: No / N.A.

13. No written permission: No / N.A.

Animals

14. Live animals, lasting harm: No / N.A.

15. Live animals, harm: No / N.A.

16. Source of dead animals, illegal: No / N.A.

General Considerations

17. Cooperating institution: No / N.A.

18. Risk to researcher/s: No / N.A.

19. Risk to environment: No / N.A.

20. Commercial sensitivity: No / N.A.

Other Potential Risks

21. Other potential risks: No / N.A.

22. Official statement: Do you require an official statement from the F/REC that this submission has abided by the UM's REDP procedures?

No / N.A.

Part 3: Submission

Which F/REC are you submitting to? * Faculty of Health Sciences

Attachments:

- [x] Information and/or recruitment letter*
- [x] Consent forms (adult participants)*
- [ ] Consent forms for legally responsible parents/guardians, in case of minors and/or adults unable to give consent*
- [ ] Assent forms in case of minors and/or adults unable to give consent*
- [x] Data collection tools (interview questions, questionnaire etc.)
- [x] Data Management Plan
- [ ] Data controller permission in case of use of unpublished secondary data
- [ ] Licence/permission to use research tools (e.g. constructs/tests)
- [ ] Any permits required for import or export of materials or data
- [ ] Letter granting institutional approval for access to participants
- [ ] Institutional approval for access to data
- [x] Letter granting institutional approval from person directly responsible for participants
- [ ] Other

Please feel free to add a cover note or any remarks to F/REC

Declarations: *

- [x] I hereby confirm having read the University of Malta Research Code of Practice and the University of Malta Research Ethics Review Procedures.
- [x] I hereby confirm that the answers to the questions above reflect the contents of the research proposal and that the information provided above is truthful.
- [x] I hereby give consent to the University Research Ethics Committee to process my personal data for the purpose of evaluating my request, audit and other matters related to this application. I understand that I have a right of access to my personal data and to obtain the rectification, erasure or restriction of processing in accordance with data protection law and in particular the General Data Protection Regulation (EU 2016/679, repealing Directive 95/46/EC) and national legislation that implements and further specifies the relevant provisions of said Regulation.

Applicant Signature: * Gianluca Pollacco

Date of Submission: * 10/04/2022

If applicable: Date collection start date 01/03/2022

Administration

REDP Application ID FHS-2022-00019

Current Status Approved

If a submitted application needs to be amended, it can be withdrawn, edited, and resubmitted, and it will retain the same reference number. There is no need to submit a new application.

Appendix Form 7.: REDP Form: Supervisor Endorsement

L-Università ta' Malta

Gianluca Pollacco <gianluca.pollacco.13@um.edu.mt>

The status of your REDP form (FHS-2022-00019) has been updated to Endorsed by supervisor

form.urec@um.edu.mt <form.urec@um.edu.mt> 11 April 2022 at 10:44
To: gianluca.pollacco.13@um.edu.mt

Dear Gianluca Pollacco,

Please note that the status of your REDP form (FHS-2022-00019) has been set to *Endorsed by supervisor*.

Your form has now been received by F/REC. As you submitted this for F/REC REVIEW, then please wait for the F/REC approval before starting data collection.

You can keep track of your applications by visiting: https://www.um.edu.mt/research/ethics/redp-form/frontEnd/.

*****This email has been automatically generated by URECA. Please do not reply. If you wish to communicate with your F/REC please use the respective email address.*****

Appendix Form 8.: UREC Form: Approval

L-Università ta' Malta

Gianluca Pollacco <gianluca.pollacco.13@um.edu.mt>

FHS-2022-00019 Gianluca Pollacco

Rita Pace Parascandalo <rita.pace-parascandalo@um.edu.mt> 11 April 2022 at 17:05
To: Gianluca Pollacco <gianluca.pollacco.13@um.edu.mt>
Cc: Research Ethics HEALTHSCI <research-ethics.healthsci@um.edu.mt>, Gatt Alfred <alfred.gatt@um.edu.mt>, Darren Sillato <sillato@gmail.com>

Dear Gianluca,

all issues raised by UREC have been addressed in your amendments. Hence, approval for your study is granted oBo FREC. You may proceed with your study and collect the data.

Good luck

Regards
Dr Rita PP

L-Università ta' Malta

Dr Rita Pace Parascandalo PhD (UCLan)
BSc(Hons) (Melit.), MSc(Melit.), RM

Senior Lecturer, Department of Midwifery

Chairperson, Faculty Research Ethics Committee

Faculty of Health Sciences
Office No. 48
+356 2340 1176
rita.pace-parascandalo@um.edu.mt

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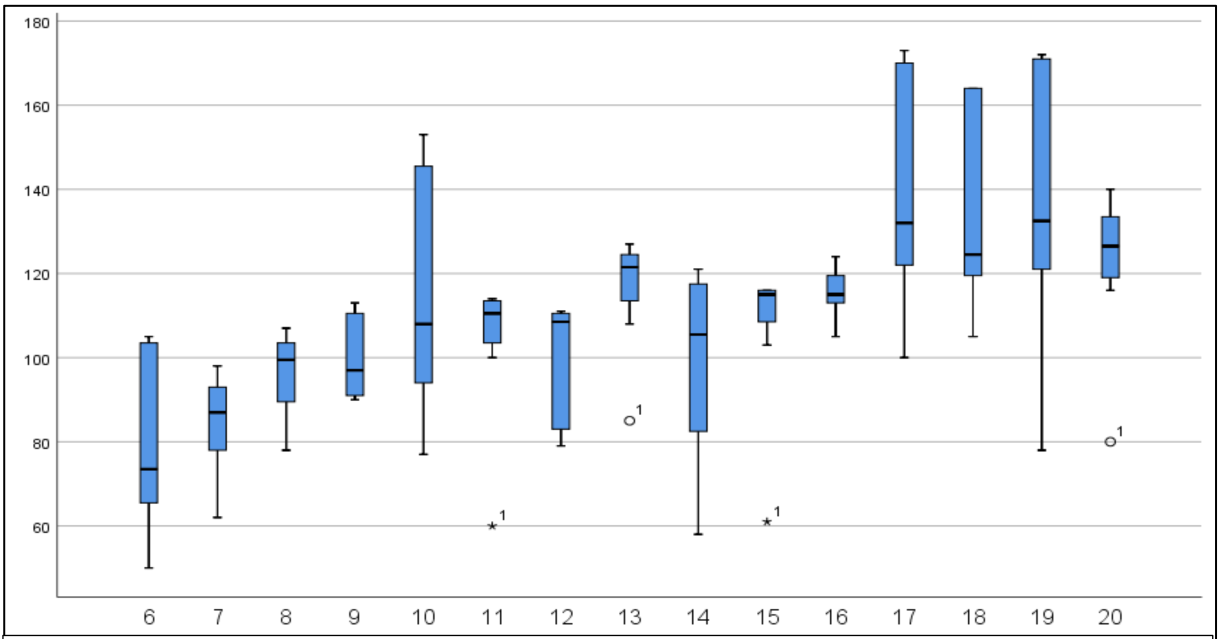
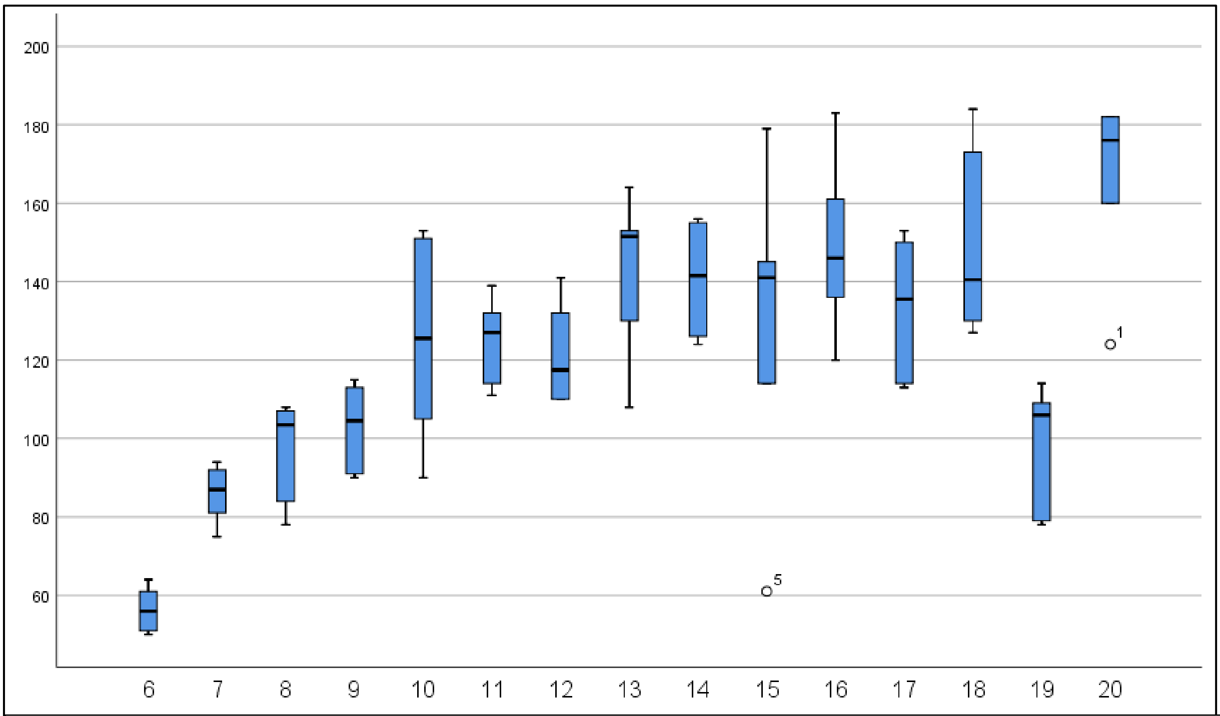
Appendix 2: Figures and Tables

- Appendix Table 2.3: Comparison of sedentary participants' mean pre- and post- kinematic and kinetic readings at Heel Strike (Paired Samples T test)
- Appendix Table 2.4: Comparison of all mean pre- and post- kinematic and kinetic readings at Mid-stance (Paired Samples T test)
- Appendix Table 2.5: Comparison of active participants' mean pre- and post- kinematic and kinetic readings at Mid-Stance (Paired Samples T test)
- Appendix Table 2.6: Comparison of sedentary participants' mean pre- and post- kinematic and kinetic readings at Mid-Stance (Paired Samples T test)
- Appendix Table 2.7: Comparison of all mean pre- and post- kinematic and kinetic readings at Weight-Transference (Paired Samples T test)
- Appendix Table 2.8: Comparison of active participants' mean pre- and post- kinematic and kinetic readings at Weight-Transference (Paired Samples T test)
- Appendix Table 2.9: Comparison of sedentary participants' mean pre- and post- kinematic and kinetic readings at Weight-Transference (Paired Samples T test)
- Appendix Table 2.10: Comparison of all mean pre- and post- kinematic and kinetic readings at Toe-Off (Paired Samples T test)
- Appendix Table 2.11: Comparison of active participants' mean pre- and post- kinematic and kinetic readings at Toe-Off (Paired Samples T test)
- Appendix Table 2.12: Comparison of sedentary mean pre- and post- kinematic and kinetic readings at Toe-Off (Paired Samples T test)
- Appendix Table 2.13: Comparison of all mean pre- and post- kinematic and kinetic readings at Mid-Swing (Paired Samples T test)
- Appendix Table 2.14: Comparison of active participants' mean pre- and post- kinematic and kinetic readings at Mid-Swing (Paired Samples T test)
- Appendix Table 2.15: Comparison of sedentary mean pre- and post- kinematic and kinetic readings at Mid-Swing (Paired Samples T test)
- Appendix Table 2.16: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Heel-Strike (Independent Samples T-test)
- Appendix Table 2.17: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Mid-Stance (Independent Samples T-test).

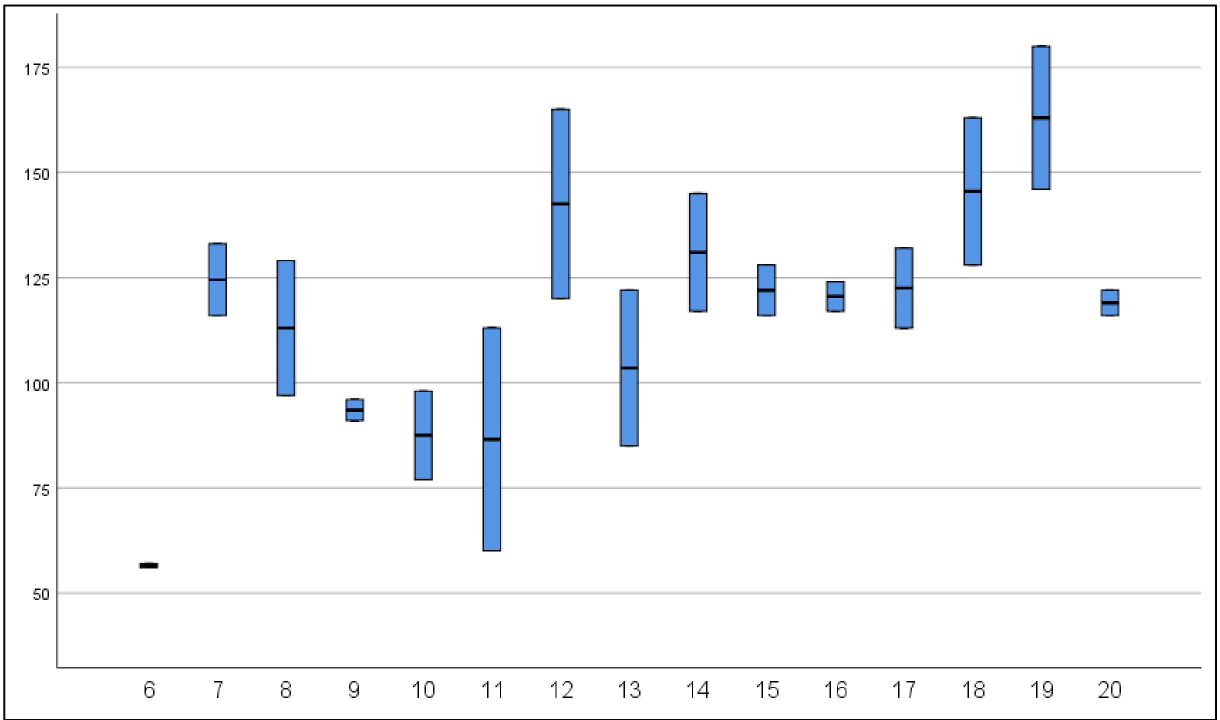
- Appendix Table 2.18: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Weight Transference (Independent Samples T-test)
- Appendix Table 2.19: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Toe-off (Independent Samples T-test)
- Appendix Table 2.20: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Mid-Swing (Independent Samples T-test)
- Appendix Table 2.21: Comparison of all mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)
- Appendix Table 2.22: Comparison of Active participants' mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)
- Appendix Table 2.23: Comparison of Sedentary participants' mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)



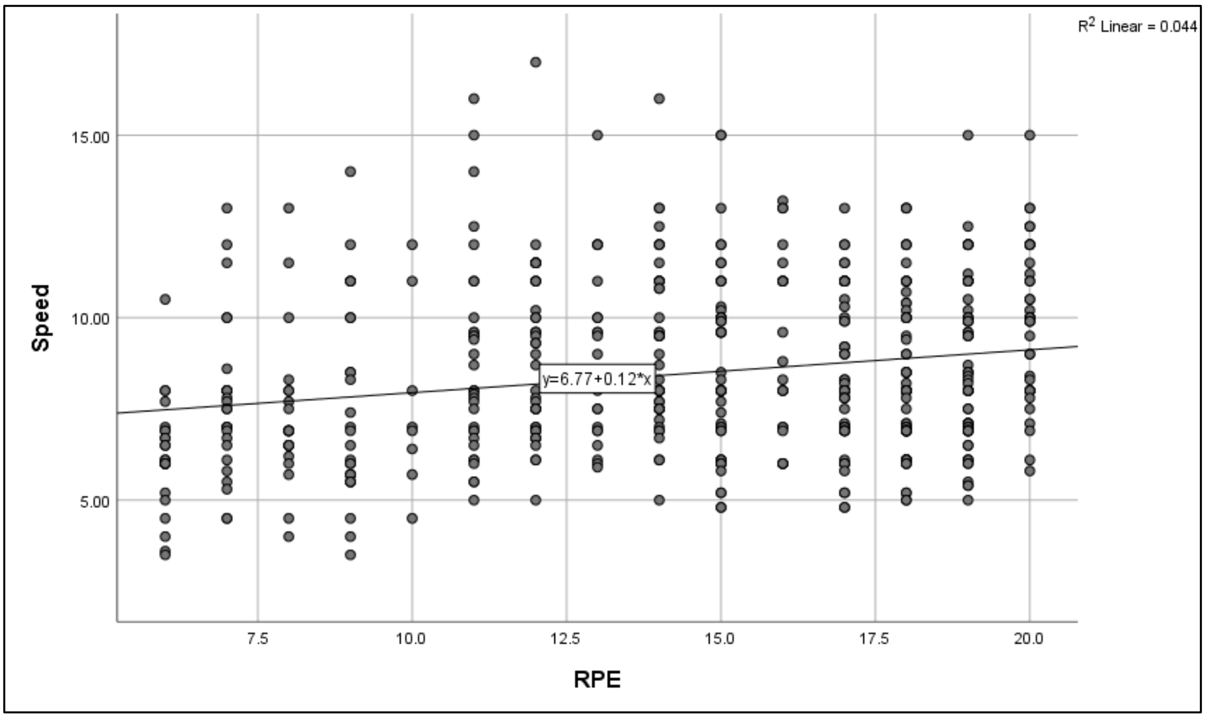
Appendix Figure 2.1: Box-plot of all Heart Rate measures of both Active and Sedentary vs RPE.



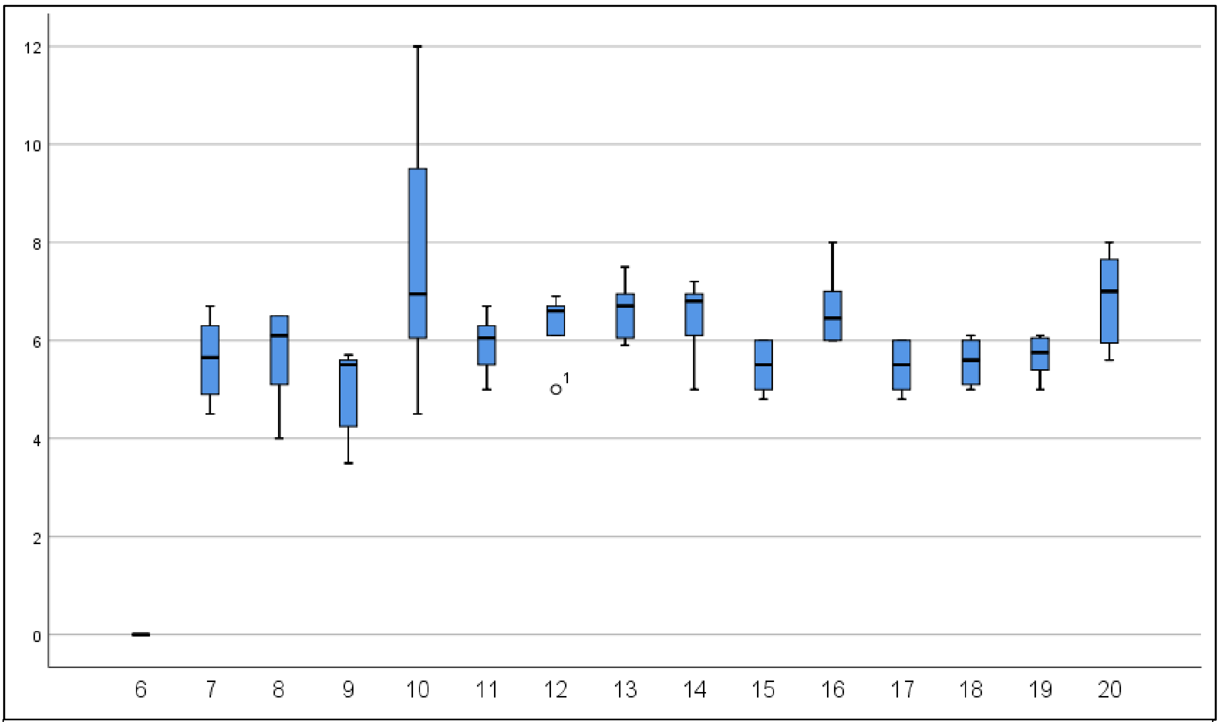
Appendix Figure 2.2: Box-plot of the Heart Rate measures of Active Participants vs RPE.



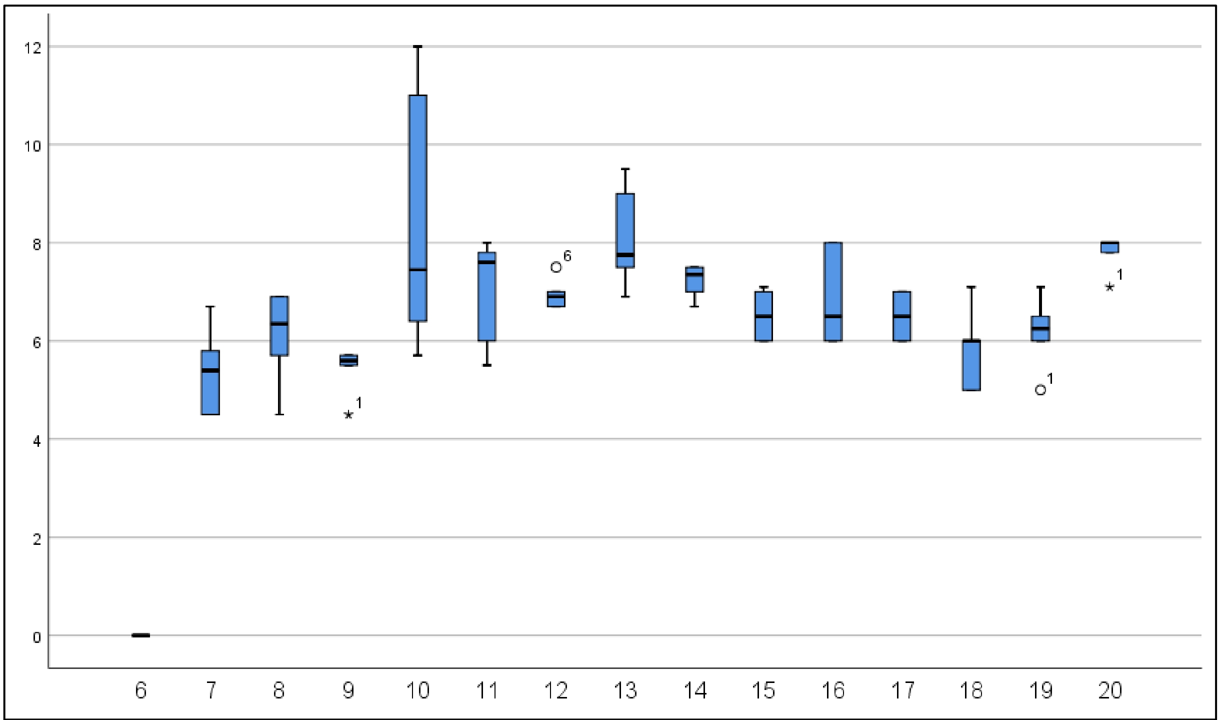
Appendix Figure 2.3: Box-plot of the Heart Rate measures of Sedentary Participants vs RPE.



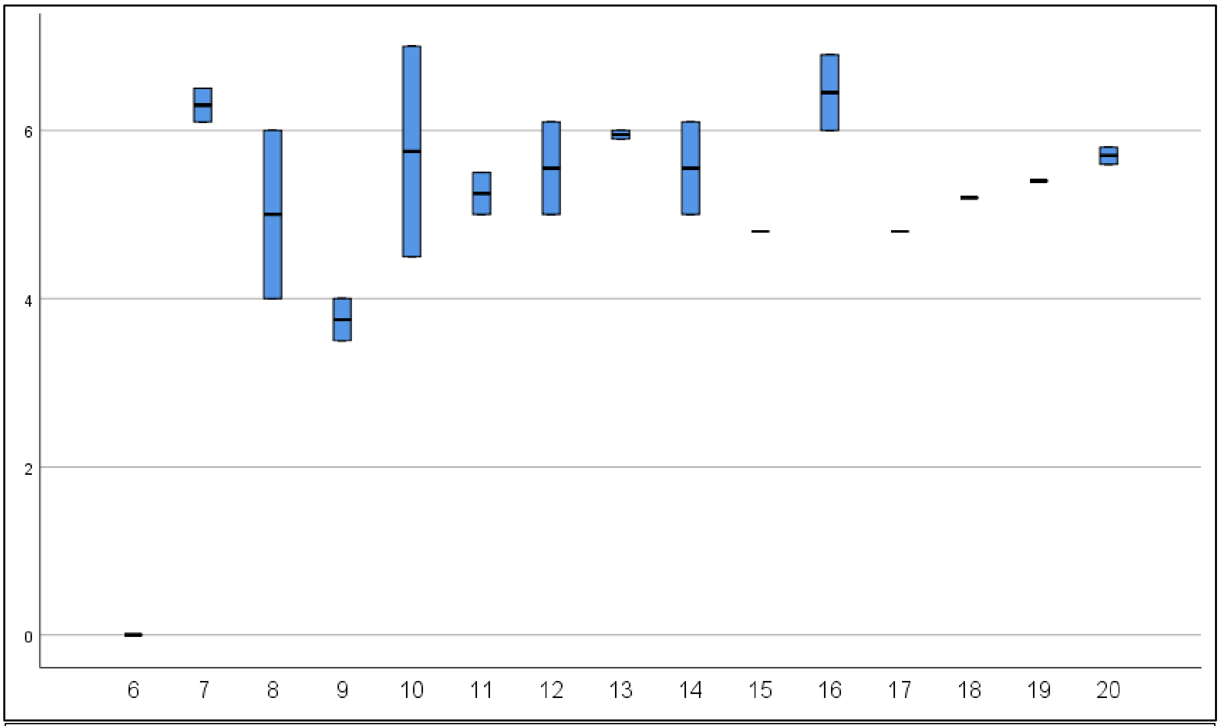
Appendix Figure 2.4: Scatter plot of the Speed readings of both Active and Sedentary participants vs RPE.



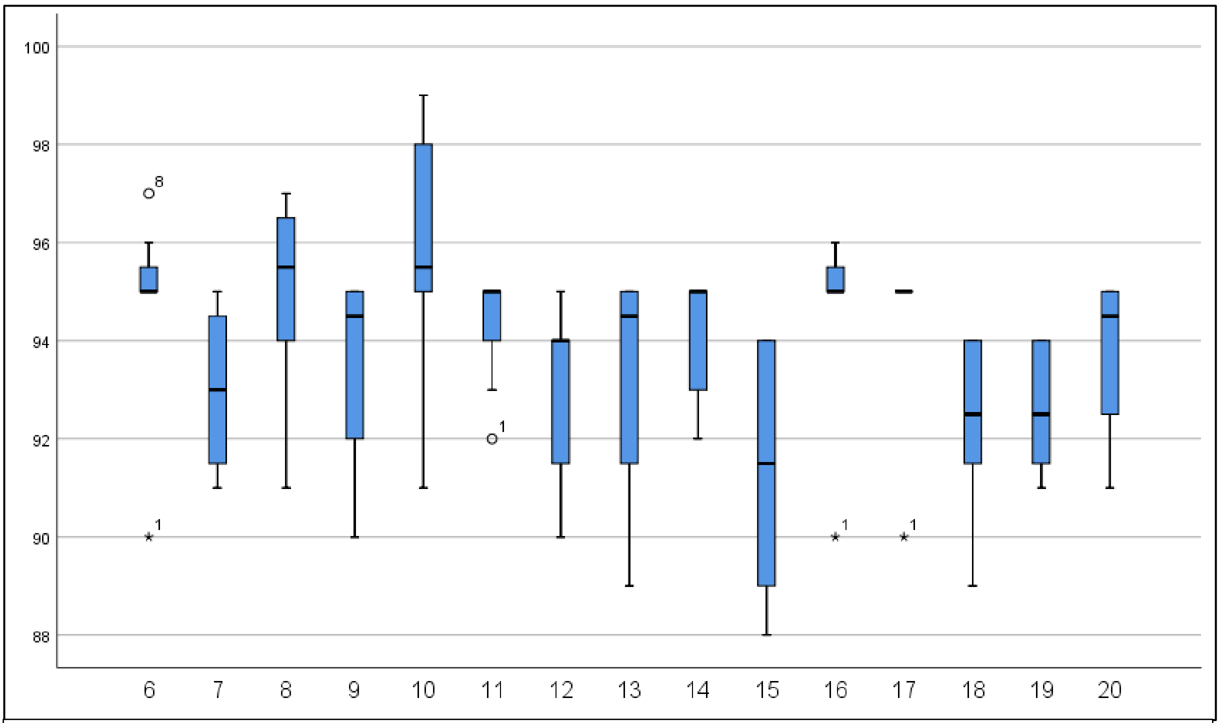
Appendix Figure 2.5: Box-plot of the Speed measures of both Active and Sedentary Participants vs RPE.



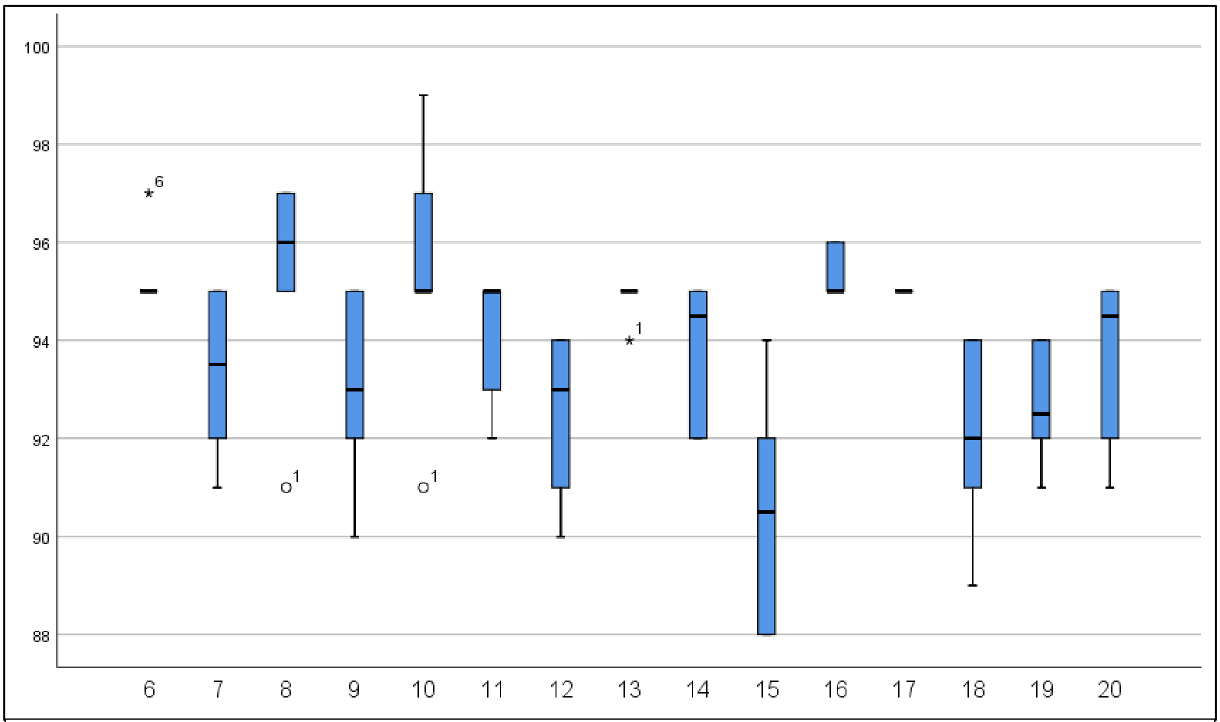
Appendix Figure 2.6: Box-plot of the Speed measures of Active Participants vs RPE.



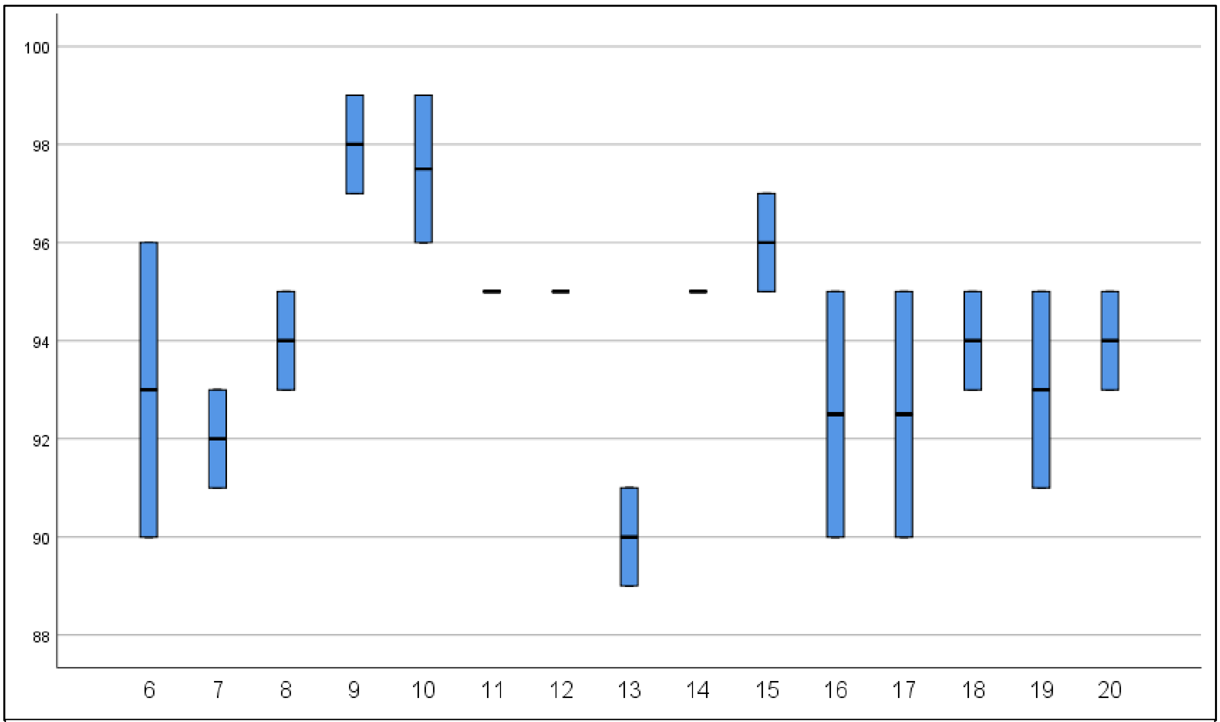
Appendix Figure 2.7: Box-plot of the Speed measures of Sedentary Participants vs RPE.



Appendix Figure 2.8: Box-plot of the SpO_2 measures of both Active and Sedentary Participants vs RPE.



Appendix Figure 2.9: Box-plot of the SpO_2 measures of Active Participants vs RPE.

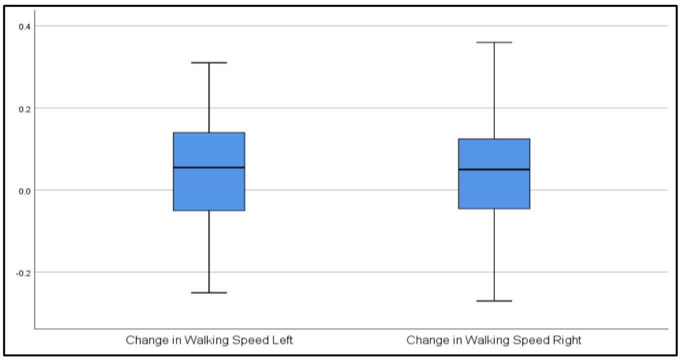


Appendix Figure 2.10: Box-plot of the SpO_2 measures of Sedentary Participants vs RPE.

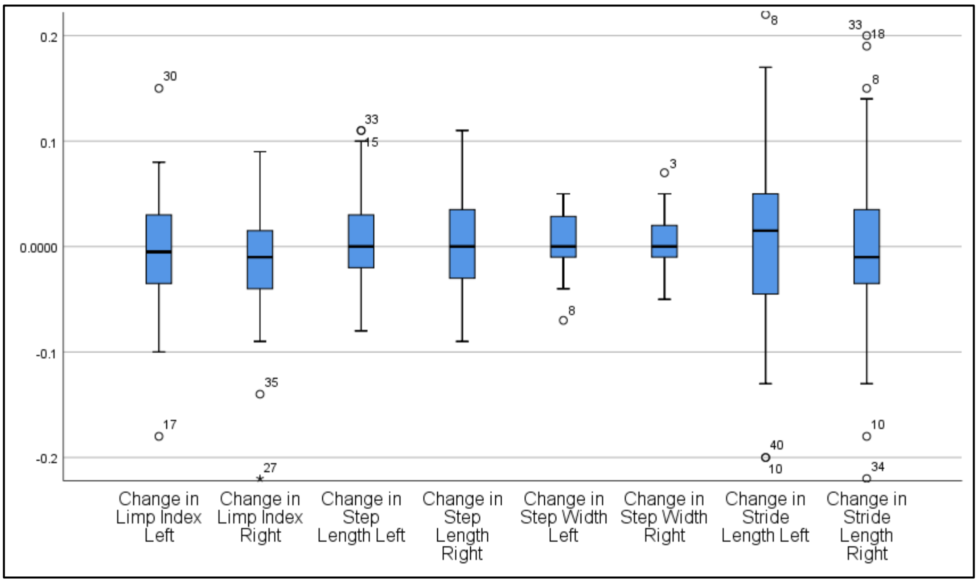
Appendix Figure 2.11: Table and Box-plot outlining the marginal changes in walking speed pre and walking speed post between Active and Sedentary Participants.

Statistics

		Change in Walking Speed Left	Change in Walking Speed Right
N	Valid	40	40
	Missing	0	0
Median		.0550	.0500
Minimum		-.25	-.27
Maximum		.31	.36
Percentiles	25	-.0500	-.0475
	50	.0550	.0500
	75	.1400	.1275



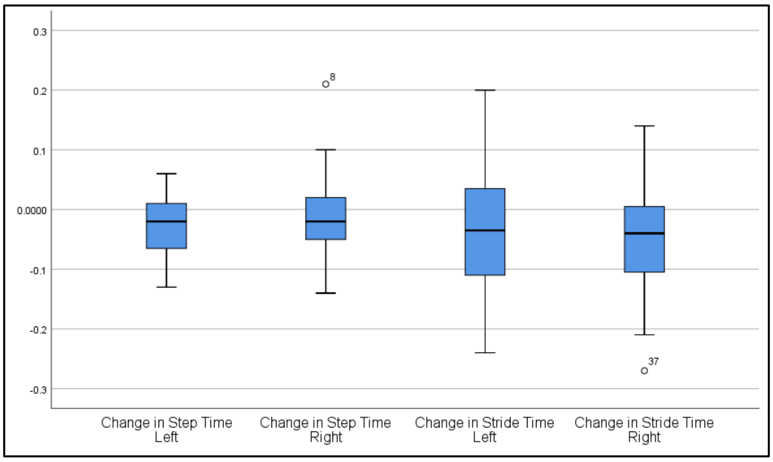
Appendix Figure 2.12: Box-plot and Table outlining the changes in spatio-temporal parameters pre and spatio-temporal parameters post in both Active and Sedentary Participants.



Statistics

		Change in Limp Index Left	Change in Limp Index Right	Change in Step Length Left	Change in Step Length Right	Change in Step Width Left	Change in Step Width Right	Change in Stride Length Left	Change in Stride Length Right
N	Valid	40	40	40	40	40	40	40	40
	Missing	0	0	0	0	0	0	0	0
Median		-.0050	-.0100	.0000	.0000	.0000	.0000	.0150	-.0100
Minimum		-.18	-.92	-.08	-.09	-.07	-.05	-.20	-.22
Maximum		.41	.09	.11	.11	.05	.07	.22	.20
Percentiles	25	-.0375	-.0400	-.0200	-.0350	-.0100	-.0100	-.0475	-.0375
	50	-.0050	-.0100	.0000	.0000	.0000	.0000	.0150	-.0100
	75	.0300	.0175	.0300	.0375	.0293	.0200	.0500	.0375

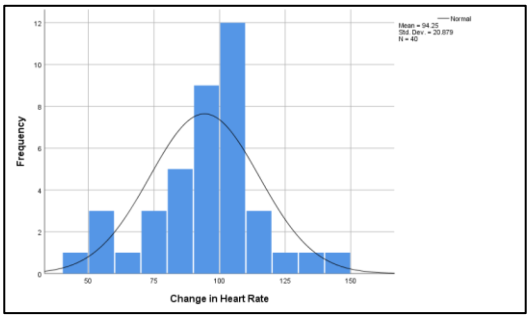
Appendix Figure 2.13: Box-plot and Table outlining the changes in spatio-temporal parameters (times) pre and spatio-temporal parameters (times) post in both Active and Sedentary Participants.

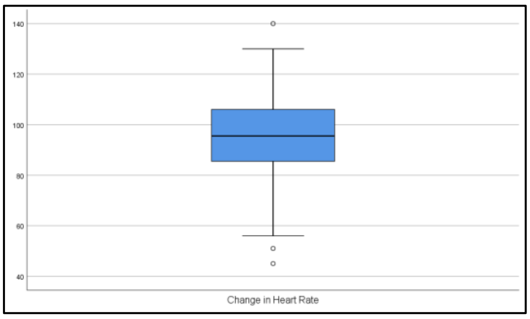


Statistics

		Change in Step Time Left	Change in Step Time Right	Change in Stride Time Left	Change in Stride Time Right
N	Valid	40	40	40	40
	Missing	0	0	0	0
Median		-.0200	-.0200	-.0350	-.0400
Minimum		-.13	-.14	-.24	-.27
Maximum		.06	.21	.20	.14
Percentiles	25	-.0675	-.0500	-.1100	-.1075
	50	-.0200	-.0200	-.0350	-.0400
	75	.0100	.0200	.0375	.0075

Appendix Figure 2.14: Box-plot and Table outlining the changes in HR parameters pre and HR parameters post in both Active and Sedentary Participants.





Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Change in Heart Rate	40	-4	140	86.43	28.640
Heart Rate Range	40	45	140	94.25	20.879
Valid N (listwise)	40				

Appendix Table 2.1: Statistical testing of mean pre- and post- kinematic and kinetic readings at Heel Strike from all participants (Paired Samples T test) * denotes significant p-values

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.111	40	6.09552	0.859585
	Post	6.052	40	6.28768	
Pelvic Tilt (Right)	Pre	6.02	40	6.08200	0.177684
	Post	5.622	40	5.99252	
Hip Flexion/Extension (Left)	Pre	15.937	40	9.79563	0.159842
	Post	16.879	40	9.64737	
Hip Flexion/Extension (Right)	Pre	17.102	40	9.46478	0.4482633
	Post	16.472	40	10.07614	
Knee Flexion/Extension (Left)	Pre	10.995	40	8.03775	0.1056829
	Post	12.057	40	8.39388	
Knee Flexion/Extension (Right)	Pre	12.069	40	7.52935	0.4872977
	Post	11.618	40	7.35243	
Ankle Dorsi/Plantar Flexion (Left)	Pre	3.053	40	7.98583	0.8243129
	Post	3.137	40	7.79946	
Ankle Dorsi/Plantar Flexion (Right)	Pre	2.835	40	8.89174	0.9970339
	Post	2.833	40	8.43476	
GRF X-axis (Left)	Pre	-0.018	40	0.55412	0.4037309
	Post	0.076	40	0.45828	
GRF X-axis (Right)	Pre	-0.067	40	0.44806	0.3006654
	Post	-0.175	40	0.39841	
Pelvic Obliquity (Left)	Pre	2.979	40	2.71873	0.0781459
	Post	3.361	40	2.64123	
Pelvic Obliquity (Right)	Pre	3.224	40	2.89939	0.2924372
	Post	3.461	40	2.52791	
Hip Ab/Adduction (Left)	Pre	4.709	40	9.33098	0.4327328
	Post	4.923	40	9.04113	
Hip Ab/Adduction (Right)	Pre	4.612	40	9.33846	0.5720031
	Post	4.777	40	9.12522	
Knee Ab/Adduction (Left)	Pre	1.291	40	10.54514	0.6090925
	Post	1.17	40	10.61100	
Knee Ab/Adduction (Right)	Pre	1.61	40	10.97308	0.8003333
	Post	1.668	40	11.03771	
Ankle Ab/Adduction (Left)	Pre	2.327	40	2.69729	0.6216583
	Post	2.402	40	2.69798	
Ankle Ab/Adduction (Right)	Pre	2.583	40	2.25569	0.9135466
	Post	2.561	40	2.09772	
GRF Y-axis (Left)	Pre	0.103	40	1.14776	0.1961866
	Post	-0.197	40	0.99337	
GRF Y-axis (Right)	Pre	-0.017	40	1.43066	0.2599462

	Post	-0.361	40	1.12451	
Pelvic Rotation (Left)	Pre	1.544	40	5.57481	0.4975887
	Post	1.962	40	5.22629	
Pelvic Rotation (Right)	Pre	4.948	40	4.80804	0.5919113
	Post	4.678	40	3.38078	
Hip Rotation (Left)	Pre	-1.846	40	10.20708	0.9320265
	Post	-1.925	40	11.04852	
Hip Rotation (Right)	Pre	0.055	40	9.38666	0.1050505
	Post	-1.273	40	10.18776	
Knee Rotation (Left)	Pre	3.133	40	10.40898	0.2744294
	Post	2.296	40	11.09872	
Knee Rotation (Right)	Pre	0.833	40	9.78478	0.6900063
	Post	0.492	40	10.35701	
Ankle Rotation (Left)	Pre	-10.06	40	9.91399	0.9508266
	Post	-10.01	40	10.04764	
Ankle Rotation (Right)	Pre	-9.438	40	7.76828	0.380315
	Post	-8.8	40	6.84569	
GRF Z-axis (Left)	Pre	9.584	40	0.92284	**0.0001835***
	Post	10.074	40	0.83303	
GRF Z-axis (Right)	Pre	9.841	40	1.07429	**0.003132***
	Post	10.242	40	0.86536	

Appendix Table 2.2: Comparison of active participants' mean pre- and post-kinematic and kinetic readings at Heel Strike (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.299	31	5.479	0.916
	Post	6.340	31	6.013	
Pelvic Tilt (Right)	Pre	6.124	31	5.705	0.449
	Post	5.863	31	5.717	
Hip Flexion/Extension (Left)	Pre	16.742	31	8.880	0.353
	Post	17.435	31	9.774	
Hip Flexion/Extension (Right)	Pre	17.245	31	9.677	0.754
	Post	16.958	31	9.849	
Knee Flexion/Extension (Left)	Pre	11.675	31	8.181	0.447
	Post	12.262	31	8.541	
Knee Flexion/Extension (Right)	Pre	12.033	31	7.767	0.446
	Post	11.496	31	7.847	
Ankle Dorsi/Plantar Flexion (Left)	Pre	4.114	31	4.218	0.933
	Post	4.152	31	4.317	
Ankle Dorsi/Plantar Flexion (Right)	Pre	3.710	31	4.316	0.726
	Post	3.539	31	3.422	
GRF X-axis (Left)	Pre	-0.063	31	0.553	0.262
	Post	0.079	31	0.481	
GRF X-axis (Right)	Pre	-0.029	31	0.452	0.144
	Post	-0.202	31	0.395	
Pelvic Obliquity (Left)	Pre	3.253	31	2.656	0.370
	Post	3.477	31	2.602	
Pelvic Obliquity (Right)	Pre	2.936	31	2.809	0.463
	Post	3.131	31	2.276	
Hip Ab/Adduction (Left)	Pre	5.158	31	10.404	0.885
	Post	5.204	31	10.041	
Hip Ab/Adduction (Right)	Pre	4.378	31	10.360	0.938
	Post	4.403	31	10.174	
Knee Ab/Adduction (Left)	Pre	0.878	31	11.767	0.949
	Post	0.860	31	11.848	
Knee Ab/Adduction (Right)	Pre	1.010	31	12.141	0.541
	Post	1.179	31	12.287	
Ankle Ab/Adduction (Left)	Pre	2.460	31	2.675	0.473
	Post	2.340	31	2.801	
Ankle Ab/Adduction (Right)	Pre	2.592	31	2.001	0.083
	Post	2.309	31	1.748	
GRF Y-axis (Left)	Pre	0.214	31	1.163	0.138
	Post	-0.199	31	1.081	
GRF Y-axis (Right)	Pre	0.115	31	1.424	0.144
	Post	-0.406	31	1.184	

Pelvic Rotation (Left)	Pre	1.327	31	5.333	0.812
	Post	1.507	31	4.714	
Pelvic Rotation (Right)	Pre	4.745	31	4.796	0.898
	Post	4.673	31	3.302	
Hip Rotation (Left)	Pre	-2.609	31	10.386	0.762
	Post	-2.261	31	11.194	
Hip Rotation (Right)	Pre	-0.188	31	8.494	0.060
	Post	-2.158	31	9.458	
Knee Rotation (Left)	Pre	3.484	31	10.698	0.200
	Post	2.254	31	11.571	
Knee Rotation (Right)	Pre	1.161	31	8.865	0.653
	Post	0.683	31	9.390	
Ankle Rotation (Left)	Pre	-10.123	31	9.962	0.540
	Post	-9.656	31	10.362	
Ankle Rotation (Right)	Pre	-9.648	31	7.902	0.352
	Post	-8.842	31	5.818	
GRF Z-axis (Left)	Pre	9.687	31	0.819	**<0.001***
	Post	10.169	31	0.769	
GRF Z-axis (Right)	Pre	9.860	31	0.918	**<0.001***
	Post	10.241	31	0.778	

Appendix Table 2.3: Comparison of sedentary participants' mean pre- and post-kinematic and kinetic readings at Heel Strike (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	5.466	9	8.243	0.553
	Post	5.061	9	7.464	
Pelvic Tilt (Right)	Pre	5.664	9	7.623	0.149
	Post	4.793	9	7.175	
Hip Flexion/Extension (Left)	Pre	13.162	9	12.684	0.266
	Post	14.962	9	9.494	
Hip Flexion/Extension (Right)	Pre	16.609	9	9.231	0.384
	Post	14.796	9	11.273	
Knee Flexion/Extension (Left)	Pre	8.653	9	7.484	**0.027***
	Post	11.350	9	8.319	
Knee Flexion/Extension (Right)	Pre	12.192	9	7.078	0.928
	Post	12.040	9	5.688	
Ankle Dorsi/Plantar Flexion (Left)	Pre	-0.599	9	14.994	0.716
	Post	-0.358	9	14.455	
Ankle Dorsi/Plantar Flexion (Right)	Pre	-0.180	9	17.389	0.482
	Post	0.403	9	17.156	
GRF X-axis (Left)	Pre	0.138	9	0.562	0.778
	Post	0.064	9	0.395	
GRF X-axis (Right)	Pre	-0.197	9	0.435	0.624
	Post	-0.082	9	0.418	
Pelvic Obliquity (Left)	Pre	2.036	9	2.878	**0.036***
	Post	2.960	9	2.895	
Pelvic Obliquity (Right)	Pre	4.216	9	3.158	0.386
	Post	4.596	9	3.140	
Hip Ab/Adduction (Left)	Pre	3.160	9	3.876	0.156
	Post	3.957	9	4.369	
Hip Ab/Adduction (Right)	Pre	5.418	9	4.657	0.401
	Post	6.064	9	3.917	
Knee Ab/Adduction (Left)	Pre	2.711	9	4.467	0.258
	Post	2.237	9	4.563	
Knee Ab/Adduction (Right)	Pre	3.673	9	5.295	0.464
	Post	3.354	9	4.860	
Ankle Ab/Adduction (Left)	Pre	1.868	9	2.886	**0.016***
	Post	2.613	9	2.448	
Ankle Ab/Adduction (Right)	Pre	2.552	9	3.129	0.204
	Post	3.431	9	2.984	
GRF Y-axis (Left)	Pre	-0.281	9	1.065	0.815
	Post	-0.188	9	0.653	
GRF Y-axis (Right)	Pre	-0.471	9	1.439	0.663
	Post	-0.206	9	0.935	

Pelvic Rotation (Left)	Pre	2.291	9	6.637	0.187
	Post	3.530	9	6.800	
Pelvic Rotation (Right)	Pre	5.647	9	5.072	0.438
	Post	4.695	9	3.851	
Hip Rotation (Left)	Pre	0.784	9	9.660	0.190
	Post	-0.766	9	11.103	
Hip Rotation (Right)	Pre	0.893	9	12.567	0.422
	Post	1.776	9	12.531	
Knee Rotation (Left)	Pre	1.927	9	9.843	0.545
	Post	2.443	9	9.920	
Knee Rotation (Right)	Pre	-0.300	9	13.044	0.911
	Post	-0.169	9	13.844	
Ankle Rotation (Left)	Pre	-9.829	9	10.340	0.111
	Post	-11.611	9	9.284	
Ankle Rotation (Right)	Pre	-8.712	9	7.697	0.967
	Post	-8.656	9	10.074	
GRF Z-axis (Left)	Pre	9.231	9	1.206	0.117
	Post	9.748	9	1.005	
GRF Z-axis (Right)	Pre	9.774	9	1.569	0.148
	Post	10.247	9	1.176	

Appendix Table 2.4: Comparison of all mean pre- and post- kinematic and kinetic readings at Mid-stance (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.259	40	6.094	0.545
	Post	6.058	40	6.200	
Pelvic Tilt (Right)	Pre	6.542	40	6.028	0.168
	Post	6.141	40	5.886	
Hip Flexion/Extension (Left)	Pre	0.306	40	9.725	0.681
	Post	0.538	40	9.477	
Hip Flexion/Extension (Right)	Pre	1.427	40	9.171	0.582
	Post	1.118	40	9.748	
Knee Flexion/Extension (Left)	Pre	3.550	40	6.370	0.097
	Post	4.365	40	6.423	
Knee Flexion/Extension (Right)	Pre	4.031	40	5.438	0.287
	Post	4.452	40	5.580	
Ankle Dorsi/Plantar Flexion (Left)	Pre	8.379	40	8.057	0.989
	Post	8.375	40	7.503	
Ankle Dorsi/Plantar Flexion (Right)	Pre	7.987	40	9.447	0.993
	Post	7.984	40	8.976	
GRF X-axis (Left)	Pre	-0.033	40	0.388	0.509
	Post	0.019	40	0.299	
GRF X-axis (Right)	Pre	-0.031	40	0.344	0.140
	Post	-0.141	40	0.274	
Pelvic Obliquity (Left)	Pre	-0.011	40	2.357	0.578
	Post	-0.132	40	2.243	
Pelvic Obliquity (Right)	Pre	0.135	40	2.774	0.878
	Post	0.163	40	2.556	
Hip Ab/Adduction (Left)	Pre	2.895	40	8.626	0.644
	Post	3.001	40	8.734	
Hip Ab/Adduction (Right)	Pre	2.677	40	8.961	0.905
	Post	2.709	40	9.156	
Knee Ab/Adduction (Left)	Pre	0.880	40	10.816	0.299
	Post	0.740	40	10.719	
Knee Ab/Adduction (Right)	Pre	1.502	40	11.130	0.850
	Post	1.471	40	11.075	
Ankle Ab/Adduction (Left)	Pre	1.622	40	2.638	0.843
	Post	1.587	40	2.973	
Ankle Ab/Adduction (Right)	Pre	1.782	40	2.034	0.615
	Post	1.859	40	1.894	
GRF Y-axis (Left)	Pre	0.084	40	0.221	0.527
	Post	0.053	40	0.198	
GRF Y-axis (Right)	Pre	0.037	40	0.258	0.486
	Post	-0.001	40	0.198	

Pelvic Rotation (Left)	Pre	0.454	40	4.861	0.703
	Post	0.225	40	4.037	
Pelvic Rotation (Right)	Pre	3.819	40	5.254	0.160
	Post	2.944	40	3.804	
Hip Rotation (Left)	Pre	-1.713	40	10.550	0.620
	Post	-1.288	40	10.028	
Hip Rotation (Right)	Pre	0.446	40	8.157	0.681
	Post	0.166	40	9.494	
Knee Rotation (Left)	Pre	1.808	40	9.074	0.282
	Post	0.953	40	10.059	
Knee Rotation (Right)	Pre	-1.678	40	9.121	0.568
	Post	-1.296	40	9.367	
Ankle Rotation (Left)	Pre	-7.162	40	9.834	0.838
	Post	-7.024	40	10.499	
Ankle Rotation (Right)	Pre	-5.873	40	7.593	0.662
	Post	-6.177	40	6.570	
GRF Z-axis (Left)	Pre	7.646	40	0.817	**0.006***
	Post	7.376	40	0.687	
GRF Z-axis (Right)	Pre	7.560	40	0.954	0.096
	Post	7.371	40	0.843	

Appendix Table 2.5: Comparison of active participants' mean pre- and post- kinematic and kinetic readings at Mid-Stance (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.396	31	5.262	0.832
	Post	6.312	31	5.864	
Pelvic Tilt (Right)	Pre	6.686	31	5.429	0.304
	Post	6.343	31	5.290	
Hip Flexion/Extension (Left)	Pre	1.181	31	8.244	0.808
	Post	1.037	31	9.291	
Hip Flexion/Extension (Right)	Pre	1.823	31	8.650	0.793
	Post	1.665	31	8.856	
Knee Flexion/Extension (Left)	Pre	4.138	31	5.714	0.863
	Post	4.219	31	6.162	
Knee Flexion/Extension (Right)	Pre	3.804	31	5.252	0.393
	Post	4.169	31	5.393	
Ankle Dorsi/Plantar Flexion (Left)	Pre	9.452	31	3.645	0.303
	Post	9.120	31	3.248	
Ankle Dorsi/Plantar Flexion (Right)	Pre	8.633	31	4.135	0.802
	Post	8.548	31	3.508	
GRF X-axis (Left)	Pre	-0.059	31	0.405	0.362
	Post	0.025	31	0.321	
GRF X-axis (Right)	Pre	-0.021	31	0.355	0.148
	Post	-0.151	31	0.289	
Pelvic Obliquity (Left)	Pre	0.225	31	2.318	0.575
	Post	0.076	31	2.234	
Pelvic Obliquity (Right)	Pre	-0.036	31	2.671	0.847
	Post	-0.074	31	2.467	
Hip Ab/Adduction (Left)	Pre	3.426	31	9.624	0.660
	Post	3.310	31	9.764	
Hip Ab/Adduction (Right)	Pre	2.663	31	9.913	0.980
	Post	2.657	31	10.171	
Knee Ab/Adduction (Left)	Pre	0.594	31	12.095	0.655
	Post	0.529	31	11.939	
Knee Ab/Adduction (Right)	Pre	0.940	31	12.421	0.449
	Post	1.082	31	12.434	
Ankle Ab/Adduction (Left)	Pre	1.859	31	2.565	0.168
	Post	1.598	31	3.084	
Ankle Ab/Adduction (Right)	Pre	1.862	31	1.888	0.505
	Post	1.759	31	1.656	
GRF Y-axis (Left)	Pre	0.066	31	0.235	0.662
	Post	0.039	31	0.215	
GRF Y-axis (Right)	Pre	0.056	31	0.272	0.369
	Post	-0.006	31	0.209	

Pelvic Rotation (Left)	Pre	0.711	31	4.949	0.350
	Post	0.105	31	3.814	
Pelvic Rotation (Right)	Pre	3.833	31	5.084	0.400
	Post	3.285	31	3.035	
Hip Rotation (Left)	Pre	-2.571	31	10.708	0.312
	Post	-1.490	31	10.382	
Hip Rotation (Right)	Pre	0.286	31	7.368	0.410
	Post	-0.421	31	9.070	
Knee Rotation (Left)	Pre	2.478	31	8.790	**0.040***
	Post	0.603	31	10.499	
Knee Rotation (Right)	Pre	-1.413	31	7.523	0.819
	Post	-1.223	31	7.760	
Ankle Rotation (Left)	Pre	-7.668	31	9.606	0.142
	Post	-6.585	31	11.078	
Ankle Rotation (Right)	Pre	-6.390	31	7.365	0.781
	Post	-6.632	31	5.679	
GRF Z-axis (Left)	Pre	7.714	31	0.829	**0.011***
	Post	7.416	31	0.686	
GRF Z-axis (Right)	Pre	7.683	31	0.800	0.122
	Post	7.475	31	0.737	

Appendix Table 2.6: Comparison of sedentary participants' mean pre- and post-kinematic and kinetic readings at Mid-Stance (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	5.788	9	8.767	0.331
	Post	5.182	9	7.571	
Pelvic Tilt (Right)	Pre	6.044	9	8.140	0.352
	Post	5.449	9	7.954	
Hip Flexion/Extension (Left)	Pre	-2.708	9	13.893	0.327
	Post	-1.181	9	10.481	
Hip Flexion/Extension (Right)	Pre	0.064	9	11.257	0.584
	Post	-0.768	9	12.805	
Knee Flexion/Extension (Left)	Pre	1.521	9	8.332	**0.016***
	Post	4.869	9	7.641	
Knee Flexion/Extension (Right)	Pre	4.814	9	6.309	0.554
	Post	5.428	9	6.430	
Ankle Dorsi/Plantar Flexion (Left)	Pre	4.683	9	15.710	**0.043***
	Post	5.810	9	15.011	
Ankle Dorsi/Plantar Flexion (Right)	Pre	5.761	9	19.074	0.668
	Post	6.040	9	18.470	
GRF X-axis (Left)	Pre	0.059	9	0.331	0.699
	Post	-0.001	9	0.220	
GRF X-axis (Right)	Pre	-0.065	9	0.320	0.748
	Post	-0.108	9	0.227	
Pelvic Obliquity (Left)	Pre	-0.827	9	2.445	0.951
	Post	-0.847	9	2.252	
Pelvic Obliquity (Right)	Pre	0.724	9	3.200	0.585
	Post	0.980	9	2.838	
Hip Ab/Adduction (Left)	Pre	1.067	9	3.253	**0.041***
	Post	1.937	9	3.561	
Hip Ab/Adduction (Right)	Pre	2.726	9	4.788	0.840
	Post	2.888	9	4.554	
Knee Ab/Adduction (Left)	Pre	1.865	9	4.507	0.249
	Post	1.467	9	4.986	
Knee Ab/Adduction (Right)	Pre	3.440	9	4.464	**0.050***
	Post	2.813	9	3.952	
Ankle Ab/Adduction (Left)	Pre	0.807	9	2.880	0.077
	Post	1.549	9	2.722	
Ankle Ab/Adduction (Right)	Pre	1.508	9	2.586	0.104
	Post	2.203	9	2.650	
GRF Y-axis (Left)	Pre	0.146	9	0.163	0.473
	Post	0.100	9	0.121	
GRF Y-axis (Right)	Pre	-0.025	9	0.204	0.529
	Post	0.017	9	0.166	

Pelvic Rotation (Left)	Pre	-0.433	9	4.714	0.483
	Post	0.641	9	4.964	
Pelvic Rotation (Right)	Pre	3.770	9	6.135	0.244
	Post	1.769	9	5.830	
Hip Rotation (Left)	Pre	1.240	9	9.998	0.053
	Post	-0.590	9	9.240	
Hip Rotation (Right)	Pre	0.994	9	10.970	0.061
	Post	2.188	9	11.182	
Knee Rotation (Left)	Pre	-0.503	9	10.192	0.058
	Post	2.157	9	8.820	
Knee Rotation (Right)	Pre	-2.589	9	13.862	0.221
	Post	-1.550	9	14.207	
Ankle Rotation (Left)	Pre	-5.418	9	11.001	**0.029***
	Post	-8.537	9	8.593	
Ankle Rotation (Right)	Pre	-4.091	9	8.547	0.575
	Post	-4.610	9	9.271	
GRF Z-axis (Left)	Pre	7.409	9	0.769	0.349
	Post	7.236	9	0.712	
GRF Z-axis (Right)	Pre	7.137	9	1.333	0.574
	Post	7.013	9	1.116	

Appendix Table 2.7: Comparison of all mean pre- and post- kinematic and kinetic readings at Weight-Transference (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	7.927	40	5.867	0.785
	Post	7.841	40	5.914	
Pelvic Tilt (Right)	Pre	8.068	40	6.145	0.629
	Post	7.920	40	6.108	
Hip Flexion/Extension (Left)	Pre	-13.231	40	8.326	0.724
	Post	-13.387	40	7.963	
Hip Flexion/Extension (Right)	Pre	-12.501	40	8.272	0.840
	Post	-12.406	40	8.408	
Knee Flexion/Extension (Left)	Pre	2.738	40	6.103	0.485
	Post	3.148	40	5.729	
Knee Flexion/Extension (Right)	Pre	2.653	40	4.711	0.240
	Post	3.330	40	5.187	
Ankle Dorsi/Plantar Flexion (Left)	Pre	14.286	40	8.165	0.289
	Post	13.721	40	8.347	
Ankle Dorsi/Plantar Flexion (Right)	Pre	14.463	40	9.888	**0.002***
	Post	13.547	40	9.990	
GRF X-axis (Left)	Pre	-0.050	40	0.504	0.244
	Post	0.070	40	0.415	
GRF X-axis (Right)	Pre	0.024	40	0.597	0.060
	Post	-0.211	40	0.457	
Pelvic Obliquity (Left)	Pre	-0.582	40	2.402	**0.020***
	Post	-0.994	40	2.071	
Pelvic Obliquity (Right)	Pre	-0.417	40	2.639	0.198
	Post	-0.639	40	2.381	
Hip Ab/Adduction (Left)	Pre	2.038	40	8.569	0.060
	Post	1.525	40	8.285	
Hip Ab/Adduction (Right)	Pre	1.927	40	8.956	0.145
	Post	1.538	40	8.968	
Knee Ab/Adduction (Left)	Pre	0.629	40	10.674	0.907
	Post	0.640	40	10.705	
Knee Ab/Adduction (Right)	Pre	1.170	40	10.905	0.674
	Post	1.106	40	10.854	
Ankle Ab/Adduction (Left)	Pre	1.548	40	2.687	0.223
	Post	1.332	40	2.900	
Ankle Ab/Adduction (Right)	Pre	1.606	40	2.212	0.903
	Post	1.629	40	1.877	
GRF Y-axis (Left)	Pre	0.114	40	1.341	0.262
	Post	0.416	40	1.142	
GRF Y-axis (Right)	Pre	0.073	40	1.204	0.206
	Post	0.389	40	0.959	

Pelvic Rotation (Left)	Pre	-2.851	40	5.034	**0.047***
	Post	-4.011	40	3.459	
Pelvic Rotation (Right)	Pre	-0.117	40	5.813	0.354
	Post	-0.600	40	4.857	
Hip Rotation (Left)	Pre	0.901	40	10.559	0.926
	Post	0.824	40	10.599	
Hip Rotation (Right)	Pre	3.301	40	7.619	**0.025***
	Post	1.808	40	8.825	
Knee Rotation (Left)	Pre	1.274	40	8.650	0.337
	Post	0.571	40	9.934	
Knee Rotation (Right)	Pre	-2.511	40	9.910	0.419
	Post	-1.804	40	9.702	
Ankle Rotation (Left)	Pre	-6.835	40	9.102	0.071
	Post	-5.737	40	9.846	
Ankle Rotation (Right)	Pre	-5.039	40	7.964	0.999
	Post	-5.039	40	6.755	
GRF Z-axis (Left)	Pre	10.194	40	0.856	0.378
	Post	10.118	40	0.879	
GRF Z-axis (Right)	Pre	10.140	40	0.720	0.098
	Post	10.272	40	0.756	

Appendix Table 2.8: Comparison of active participants' mean pre- and post- kinematic and kinetic readings at Weight-Transference (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	8.03	31	5.166	0.830
	Post	8.11	31	5.705	
Pelvic Tilt (Right)	Pre	8.26	31	5.544	0.720
	Post	8.13	31	5.609	
Hip Flexion/Extension (Left)	Pre	-12.90	31	7.310	0.761
	Post	-13.05	31	7.842	
Hip Flexion/Extension (Right)	Pre	-12.25	31	7.884	0.933
	Post	-12.21	31	8.159	
Knee Flexion/Extension (Left)	Pre	2.70	31	5.310	0.485
	Post	3.14	31	5.307	
Knee Flexion/Extension (Right)	Pre	2.32	31	4.665	0.403
	Post	2.83	31	4.978	
Ankle Dorsi/Plantar Flexion (Left)	Pre	15.29	31	4.691	0.064
	Post	14.35	31	4.669	
Ankle Dorsi/Plantar Flexion (Right)	Pre	15.25	31	4.654	**0.014***
	Post	14.37	31	4.906	
GRF X-axis (Left)	Pre	-0.09	31	0.528	0.150
	Post	0.08	31	0.452	
GRF X-axis (Right)	Pre	0.05	31	0.607	0.057
	Post	-0.23	31	0.483	
Pelvic Obliquity (Left)	Pre	-0.46	31	2.099	0.098
	Post	-0.81	31	1.861	
Pelvic Obliquity (Right)	Pre	-0.66	31	2.520	0.176
	Post	-0.91	31	2.315	
Hip Ab/Adduction (Left)	Pre	2.51	31	9.489	**0.031***
	Post	1.85	31	9.256	
Hip Ab/Adduction (Right)	Pre	2.09	31	9.812	0.152

	Post	1.66	31	9.801	
Knee Ab/Adduction (Left)	Pre	0.43	31	11.936	0.863
	Post	0.45	31	11.969	
Knee Ab/Adduction (Right)	Pre	0.70	31	12.250	0.558
	Post	0.79	31	12.236	
Ankle Ab/Adduction (Left)	Pre	1.82	31	2.628	**0.039***
	Post	1.44	31	3.013	
Ankle Ab/Adduction (Right)	Pre	1.79	31	1.991	0.233
	Post	1.61	31	1.695	
GRF Y-axis (Left)	Pre	-0.09	31	1.300	0.119
	Post	0.39	31	1.188	
GRF Y-axis (Right)	Pre	-0.01	31	1.169	0.205
	Post	0.36	31	1.016	
Pelvic Rotation (Left)	Pre	-2.56	31	4.672	**0.037***
	Post	-3.91	31	3.705	
Pelvic Rotation (Right)	Pre	0.08	31	5.134	0.640
	Post	-0.18	31	3.704	
Hip Rotation (Left)	Pre	-0.02	31	10.956	0.733
	Post	0.34	31	11.154	
Hip Rotation (Right)	Pre	3.00	31	7.254	**0.021***
	Post	1.06	31	8.566	
Knee Rotation (Left)	Pre	1.77	31	8.357	0.213
	Post	0.67	31	10.510	
Knee Rotation (Right)	Pre	-2.33	31	8.430	0.448
	Post	-1.49	31	7.924	
Ankle Rotation (Left)	Pre	-7.19	31	9.184	**0.038***
	Post	-5.80	31	10.342	
Ankle Rotation (Right)	Pre	-5.64	31	7.610	0.881
	Post	-5.77	31	5.846	

GRF Z-axis (Left)	Pre	10.36	31	0.696	0.673
	Post	10.33	31	0.675	
GRF Z-axis (Right)	Pre	10.22	31	0.665	0.066
	Post	10.36	31	0.693	

Appendix Table 2.9: Comparison of sedentary participants' mean pre- and post- kinematic and kinetic readings at Weight-Transference (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	7.572	9	8.216	0.378
	Post	6.928	9	6.873	
Pelvic Tilt (Right)	Pre	7.411	9	8.258	0.712
	Post	7.207	9	7.945	
Hip Flexion/Extension (Left)	Pre	-14.353	9	11.651	0.870
	Post	-14.541	9	8.750	
Hip Flexion/Extension (Right)	Pre	-13.353	9	9.970	0.761
	Post	-13.097	9	9.712	
Knee Flexion/Extension (Left)	Pre	2.883	9	8.706	0.846
	Post	3.188	9	7.374	
Knee Flexion/Extension (Right)	Pre	3.783	9	4.971	0.433
	Post	5.067	9	5.820	
Ankle Dorsi/Plantar Flexion (Left)	Pre	10.833	9	15.005	0.662
	Post	11.567	9	15.848	
Ankle Dorsi/Plantar Flexion (Right)	Pre	11.767	9	19.618	**0.050***
	Post	10.724	9	19.614	
GRF X-axis (Left)	Pre	0.096	9	0.400	0.750
	Post	0.032	9	0.266	
GRF X-axis (Right)	Pre	-0.074	9	0.583	0.786
	Post	-0.135	9	0.367	
Pelvic Obliquity (Left)	Pre	-0.990	9	3.370	**0.034***
	Post	-1.619	9	2.713	
Pelvic Obliquity (Right)	Pre	0.405	9	3.025	0.808
	Post	0.298	9	2.503	
Hip Ab/Adduction (Left)	Pre	0.408	9	4.053	0.980
	Post	0.423	9	3.411	
Hip Ab/Adduction (Right)	Pre	1.351	9	5.430	0.712
	Post	1.131	9	5.620	
Knee Ab/Adduction (Left)	Pre	1.314	9	4.521	0.898
	Post	1.294	9	4.562	
Knee Ab/Adduction (Right)	Pre	2.793	9	3.629	0.109
	Post	2.188	9	3.331	
Ankle Ab/Adduction (Left)	Pre	0.619	9	2.835	0.482
	Post	0.960	9	2.595	
Ankle Ab/Adduction (Right)	Pre	0.974	9	2.901	0.292
	Post	1.697	9	2.526	
GRF Y-axis (Left)	Pre	0.816	9	1.311	0.577
	Post	0.498	9	1.024	
GRF Y-axis (Right)	Pre	0.360	9	1.351	0.806
	Post	0.483	9	0.773	

Pelvic Rotation (Left)	Pre	-3.840	9	6.348	0.728
	Post	-4.347	9	2.584	
Pelvic Rotation (Right)	Pre	-0.808	9	8.074	0.353
	Post	-2.039	9	7.781	
Hip Rotation (Left)	Pre	4.080	9	8.872	**0.048***
	Post	2.507	9	8.777	
Hip Rotation (Right)	Pre	4.331	9	9.171	0.887
	Post	4.392	9	9.737	
Knee Rotation (Left)	Pre	-0.434	9	9.929	0.594
	Post	0.222	9	8.165	
Knee Rotation (Right)	Pre	-3.148	9	14.548	0.794
	Post	-2.876	9	14.892	
Ankle Rotation (Left)	Pre	-5.624	9	9.244	0.944
	Post	-5.518	9	8.453	
Ankle Rotation (Right)	Pre	-2.979	9	9.264	0.741
	Post	-2.520	9	9.226	
GRF Z-axis (Left)	Pre	9.613	9	1.126	0.432
	Post	9.396	9	1.139	
GRF Z-axis (Right)	Pre	9.850	9	0.866	0.688
	Post	9.953	9	0.915	

Appendix Table 2.10: Comparison of all mean pre- and post- kinematic and kinetic readings at Toe-Off (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.618	40	5.901	0.173
	Post	6.153	40	6.080	
Pelvic Tilt (Right)	Pre	6.746	40	6.109	0.273
	Post	6.385	40	6.370	
Hip Flexion/Extension (Left)	Pre	-4.022	40	8.965	0.273
	Post	-3.029	40	8.629	
Hip Flexion/Extension (Right)	Pre	-3.787	40	9.355	0.079
	Post	-2.309	40	8.358	
Knee Flexion/Extension (Left)	Pre	37.273	40	14.130	0.131
	Post	39.989	40	10.634	
Knee Flexion/Extension (Right)	Pre	37.566	40	11.226	0.159
	Post	39.813	40	10.523	
Ankle Dorsi/Plantar Flexion (Left)	Pre	-6.907	40	8.729	**0.003***
	Post	-10.721	40	10.225	
Ankle Dorsi/Plantar Flexion (Right)	Pre	-7.365	40	9.917	0.093
	Post	-9.700	40	10.640	
GRF X-axis (Left)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	
GRF X-axis (Right)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	
Pelvic Obliquity (Left)	Pre	-2.995	40	2.836	**<0.001***
	Post	-3.945	40	2.646	
Pelvic Obliquity (Right)	Pre	-3.386	40	3.134	0.443
	Post	-3.545	40	2.606	
Hip Ab/Adduction (Left)	Pre	-5.393	40	9.286	**<0.001***
	Post	-7.063	40	9.102	
Hip Ab/Adduction (Right)	Pre	-5.702	40	9.514	0.083
	Post	-6.509	40	9.382	
Knee Ab/Adduction (Left)	Pre	2.128	40	10.621	0.432
	Post	2.616	40	10.593	
Knee Ab/Adduction (Right)	Pre	2.616	40	10.756	0.315
	Post	2.079	40	10.231	
Ankle Ab/Adduction (Left)	Pre	1.162	40	2.912	0.592
	Post	1.054	40	3.357	
Ankle Ab/Adduction (Right)	Pre	1.005	40	2.362	0.678
	Post	1.099	40	2.438	
GRF Y-axis (Left)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	
GRF Y-axis (Right)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	

Pelvic Rotation (Left)	Pre	-4.189	40	4.218	0.194
	Post	-4.892	40	3.144	
Pelvic Rotation (Right)	Pre	-1.888	40	5.855	0.941
	Post	-1.842	40	5.129	
Hip Rotation (Left)	Pre	-1.211	40	10.008	0.918
	Post	-1.137	40	10.560	
Hip Rotation (Right)	Pre	1.057	40	9.429	**0.028***
	Post	-0.840	40	10.068	
Knee Rotation (Left)	Pre	5.901	40	11.844	0.760
	Post	5.622	40	11.404	
Knee Rotation (Right)	Pre	2.119	40	11.982	0.324
	Post	3.163	40	11.736	
Ankle Rotation (Left)	Pre	-5.724	40	9.964	0.067
	Post	-4.595	40	11.041	
Ankle Rotation (Right)	Pre	-2.920	40	9.445	0.728
	Post	-3.245	40	8.936	
GRF Z-axis (Left)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	
GRF Z-axis (Right)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	

Appendix Table 2.11: Comparison of active participants' mean pre- and post- kinematic and kinetic readings at Toe-Off (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.496	31	5.280	0.460
	Post	6.212	31	5.669	
Pelvic Tilt (Right)	Pre	6.893	31	5.332	0.286
	Post	6.493	31	5.903	
Hip Flexion/Extension (Left)	Pre	-2.684	31	9.067	0.159
	Post	-1.321	31	8.327	
Hip Flexion/Extension (Right)	Pre	-2.730	31	9.530	0.161
	Post	-1.429	31	8.904	
Knee Flexion/Extension (Left)	Pre	40.011	31	12.951	0.221
	Post	42.406	31	8.897	
Knee Flexion/Extension (Right)	Pre	39.104	31	11.407	0.195
	Post	41.506	31	10.153	
Ankle Dorsi/Plantar Flexion (Left)	Pre	-8.137	31	6.418	**0.012***
	Post	-11.600	31	7.712	
Ankle Dorsi/Plantar Flexion (Right)	Pre	-7.461	31	7.048	0.075
	Post	-10.164	31	6.201	
GRF X-axis (Left)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	
GRF X-axis (Right)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	
Pelvic Obliquity (Left)	Pre	-2.853	31	2.817	**0.004***
	Post	-3.636	31	2.541	
Pelvic Obliquity (Right)	Pre	-3.577	31	2.774	0.446
	Post	-3.728	31	2.421	
Hip Ab/Adduction (Left)	Pre	-5.525	31	10.195	**0.002***
	Post	-7.023	31	10.054	
Hip Ab/Adduction (Right)	Pre	-5.755	31	10.227	**0.043***
	Post	-6.674	31	10.410	
Knee Ab/Adduction (Left)	Pre	2.040	31	11.890	0.572
	Post	2.404	31	11.915	
Knee Ab/Adduction (Right)	Pre	2.798	31	11.787	0.236
	Post	2.091	31	10.981	
Ankle Ab/Adduction (Left)	Pre	1.342	31	3.020	0.146
	Post	1.045	31	3.443	
Ankle Ab/Adduction (Right)	Pre	1.227	31	2.286	0.684
	Post	1.134	31	2.187	
GRF Y-axis (Left)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	
GRF Y-axis (Right)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	

Pelvic Rotation (Left)	Pre	-4.010	31	4.005	0.121
	Post	-4.941	31	3.205	
Pelvic Rotation (Right)	Pre	-1.764	31	5.494	0.699
	Post	-1.483	31	4.498	
Hip Rotation (Left)	Pre	-1.547	31	10.500	0.802
	Post	-1.346	31	11.085	
Hip Rotation (Right)	Pre	1.205	31	8.686	**0.024***
	Post	-1.218	31	9.261	
Knee Rotation (Left)	Pre	6.587	31	12.317	0.498
	Post	5.874	31	12.213	
Knee Rotation (Right)	Pre	2.289	31	10.851	0.300
	Post	3.670	31	10.634	
Ankle Rotation (Left)	Pre	-6.445	31	10.302	**0.043***
	Post	-5.063	31	11.282	
Ankle Rotation (Right)	Pre	-3.930	31	9.280	0.706
	Post	-4.369	31	8.028	
GRF Z-axis (Left)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	
GRF Z-axis (Right)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	

Appendix Table 2.12: Comparison of sedentary mean pre- and post- kinematic and kinetic readings at Toe-Off (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	7.037	9	8.059	0.162
	Post	5.950	9	7.724	
Pelvic Tilt (Right)	Pre	6.240	9	8.660	0.765
	Post	6.016	9	8.182	
Hip Flexion/Extension (Left)	Pre	-8.633	9	7.252	0.908
	Post	-8.914	9	7.259	
Hip Flexion/Extension (Right)	Pre	-7.429	9	8.175	0.319
	Post	-5.339	9	5.469	
Knee Flexion/Extension (Left)	Pre	27.844	9	14.673	0.413
	Post	31.661	9	12.398	
Knee Flexion/Extension (Right)	Pre	32.267	9	9.258	0.610
	Post	33.978	9	10.188	
Ankle Dorsi/Plantar Flexion (Left)	Pre	-2.669	9	13.816	0.119
	Post	-7.693	9	16.534	
Ankle Dorsi/Plantar Flexion (Right)	Pre	-7.037	9	17.117	0.765
	Post	-8.100	9	20.100	
GRF X-axis (Left)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	
GRF X-axis (Right)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	
Pelvic Obliquity (Left)	Pre	-3.486	9	3.017	**0.017***
	Post	-5.009	9	2.874	
Pelvic Obliquity (Right)	Pre	-2.727	9	4.288	0.780
	Post	-2.913	9	3.250	
Hip Ab/Adduction (Left)	Pre	-4.939	9	5.504	**0.027***
	Post	-7.202	9	4.981	
Hip Ab/Adduction (Right)	Pre	-5.517	9	7.002	0.774
	Post	-5.938	9	4.717	
Knee Ab/Adduction (Left)	Pre	2.428	9	4.431	0.606
	Post	3.346	9	3.730	
Knee Ab/Adduction (Right)	Pre	1.988	9	6.511	0.967
	Post	2.040	9	7.624	
Ankle Ab/Adduction (Left)	Pre	0.545	9	2.567	0.360
	Post	1.082	9	3.239	
Ankle Ab/Adduction (Right)	Pre	0.237	9	2.597	0.255
	Post	0.976	9	3.320	
GRF Y-axis (Left)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	
GRF Y-axis (Right)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	

Pelvic Rotation (Left)	Pre	-4.805	9	5.103	0.951
	Post	-4.723	9	3.102	
Pelvic Rotation (Right)	Pre	-2.313	9	7.325	0.486
	Post	-3.080	9	7.081	
Hip Rotation (Left)	Pre	-0.050	9	8.538	0.824
	Post	-0.417	9	9.057	
Hip Rotation (Right)	Pre	0.548	9	12.254	0.934
	Post	0.461	9	13.041	
Knee Rotation (Left)	Pre	3.536	9	10.336	0.529
	Post	4.753	9	8.581	
Knee Rotation (Right)	Pre	1.531	9	16.057	0.923
	Post	1.417	9	15.586	
Ankle Rotation (Left)	Pre	-3.239	9	8.779	0.864
	Post	-2.982	9	10.640	
Ankle Rotation (Right)	Pre	0.561	9	9.712	0.957
	Post	0.628	9	11.215	
GRF Z-axis (Left)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	
GRF Z-axis (Right)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	

Appendix Table 2.13: Comparison of all mean pre- and post- kinematic and kinetic readings at Mid-Swing (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.565	40	5.978	0.476
	Post	6.361	40	5.888	
Pelvic Tilt (Right)	Pre	6.427	40	5.981	0.365
	Post	6.153	40	6.109	
Hip Flexion/Extension (Left)	Pre	27.241	40	7.841	**0.038***
	Post	28.409	40	7.269	
Hip Flexion/Extension (Right)	Pre	28.133	40	7.197	0.261
	Post	28.722	40	7.037	
Knee Flexion/Extension (Left)	Pre	44.710	40	11.073	0.993
	Post	44.729	40	12.146	
Knee Flexion/Extension (Right)	Pre	45.453	40	10.985	0.727
	Post	44.779	40	10.892	
Ankle Dorsi/Plantar Flexion (Left)	Pre	1.880	40	9.031	**0.017***
	Post	0.351	40	7.986	
Ankle Dorsi/Plantar Flexion (Right)	Pre	2.011	40	11.126	**0.022***
	Post	0.546	40	9.745	
GRF X-axis (Left)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	
GRF X-axis (Right)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	
Pelvic Obliquity (Left)	Pre	0.341	40	2.515	0.931
	Post	0.323	40	2.360	
Pelvic Obliquity (Right)	Pre	0.110	40	2.409	0.645
	Post	0.217	40	2.347	
Hip Ab/Adduction (Left)	Pre	-2.561	40	9.317	**0.008***
	Post	-3.356	40	9.141	
Hip Ab/Adduction (Right)	Pre	-2.378	40	9.372	**0.021***
	Post	-3.042	40	9.036	
Knee Ab/Adduction (Left)	Pre	2.404	40	10.118	**0.001***
	Post	3.697	40	10.146	
Knee Ab/Adduction (Right)	Pre	1.815	40	10.295	**0.001***
	Post	3.783	40	11.116	
Ankle Ab/Adduction (Left)	Pre	2.773	40	2.606	0.460
	Post	2.648	40	2.720	
Ankle Ab/Adduction (Right)	Pre	2.574	40	2.316	0.999
	Post	2.574	40	2.223	
GRF Y-axis (Left)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	
GRF Y-axis (Right)	Pre	.0000a	40	0.000	1.000

	Post	.0000a	40	0.000	
Pelvic Rotation (Left)	Pre	-2.295	40	4.867	0.449
	Post	-1.865	40	3.508	
Pelvic Rotation (Right)	Pre	-1.398	40	4.720	0.064
	Post	-0.381	40	4.387	
Hip Rotation (Left)	Pre	-0.535	40	8.728	0.575
	Post	-0.978	40	10.500	
Hip Rotation (Right)	Pre	0.076	40	8.439	0.956
	Post	0.028	40	9.235	
Knee Rotation (Left)	Pre	6.171	40	12.229	**0.039***
	Post	4.817	40	12.134	
Knee Rotation (Right)	Pre	2.697	40	12.427	0.362
	Post	1.746	40	11.806	
Ankle Rotation (Left)	Pre	-12.159	40	8.424	0.257
	Post	-11.343	40	9.687	
Ankle Rotation (Right)	Pre	-9.423	40	7.633	0.963
	Post	-9.391	40	7.714	
GRF Z-axis (Left)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	
GRF Z-axis (Right)	Pre	.0000a	40	0.000	1.000
	Post	.0000a	40	0.000	

Appendix Table 2.14: Comparison of active participants' mean pre- and post-kinematic and kinetic readings at Mid-Swing (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.604	31	5.256	0.730
	Post	6.712	31	5.156	
Pelvic Tilt (Right)	Pre	6.589	31	5.154	0.504
	Post	6.366	31	5.745	
Hip Flexion/Extension (Left)	Pre	28.152	31	6.940	**0.010***
	Post	29.584	31	6.306	
Hip Flexion/Extension (Right)	Pre	28.694	31	6.660	0.288
	Post	29.287	31	6.962	
Knee Flexion/Extension (Left)	Pre	45.019	31	9.491	0.714
	Post	44.137	31	13.117	
Knee Flexion/Extension (Right)	Pre	46.290	31	10.535	0.611
	Post	45.176	31	10.840	
Ankle Dorsi/Plantar Flexion (Left)	Pre	2.953	31	4.151	0.091
	Post	1.727	31	2.771	
Ankle Dorsi/Plantar Flexion (Right)	Pre	3.165	31	4.281	**0.043***
	Post	1.808	31	2.872	
GRF X-axis (Left)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	
GRF X-axis (Right)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	
Pelvic Obliquity (Left)	Pre	0.677	31	2.386	0.997
	Post	0.678	31	2.220	
Pelvic Obliquity (Right)	Pre	-0.155	31	2.348	0.136
	Post	0.240	31	2.190	
Hip Ab/Adduction (Left)	Pre	-2.101	31	10.244	**0.021***
	Post	-2.725	31	10.011	
Hip Ab/Adduction (Right)	Pre	-2.600	31	10.422	0.195
	Post	-3.040	31	9.979	
Knee Ab/Adduction (Left)	Pre	2.781	31	11.075	**0.002***
	Post	4.146	31	10.909	
Knee Ab/Adduction (Right)	Pre	1.903	31	10.992	**0.003***
	Post	3.862	31	11.582	
Ankle Ab/Adduction (Left)	Pre	2.928	31	2.529	0.118
	Post	2.645	31	2.705	
Ankle Ab/Adduction (Right)	Pre	2.583	31	1.950	0.776
	Post	2.544	31	1.858	
GRF Y-axis (Left)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	
GRF Y-axis (Right)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	

Pelvic Rotation (Left)	Pre	-2.149	31	4.596	0.676
	Post	-1.877	31	2.929	
Pelvic Rotation (Right)	Pre	-1.407	31	4.524	**0.032***
	Post	-0.065	31	4.132	
Hip Rotation (Left)	Pre	-0.636	31	8.488	0.905
	Post	-0.746	31	10.393	
Hip Rotation (Right)	Pre	0.140	31	8.304	0.667
	Post	-0.333	31	8.889	
Knee Rotation (Left)	Pre	6.053	31	12.800	**0.004***
	Post	4.158	31	12.831	
Knee Rotation (Right)	Pre	2.446	31	12.749	0.754
	Post	2.050	31	11.381	
Ankle Rotation (Left)	Pre	-12.358	31	8.682	0.205
	Post	-11.254	31	9.763	
Ankle Rotation (Right)	Pre	-9.589	31	7.727	0.630
	Post	-9.998	31	7.079	
GRF Z-axis (Left)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	
GRF Z-axis (Right)	Pre	.0000b	31	0.000	1.000
	Post	.0000b	31	0.000	

Appendix Table 2.15: Comparison of sedentary mean pre- and post- kinematic and kinetic readings at Mid-Swing (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Pelvic Tilt (Left)	Pre	6.433	9	8.401	**0.047***
	Post	5.150	9	8.197	
Pelvic Tilt (Right)	Pre	5.870	9	8.622	0.552
	Post	5.420	9	7.575	
Hip Flexion/Extension (Left)	Pre	24.102	9	10.239	0.879
	Post	24.363	9	9.207	
Hip Flexion/Extension (Right)	Pre	26.203	9	8.988	0.688
	Post	26.773	9	7.356	
Knee Flexion/Extension (Left)	Pre	43.644	9	16.072	0.412
	Post	46.767	9	8.248	
Knee Flexion/Extension (Right)	Pre	42.567	9	12.649	0.848
	Post	43.411	9	11.619	
Ankle Dorsi/Plantar Flexion (Left)	Pre	-1.818	9	17.696	0.081
	Post	-4.389	9	15.797	
Ankle Dorsi/Plantar Flexion (Right)	Pre	-1.963	9	22.624	0.300
	Post	-3.803	9	20.114	
GRF X-axis (Left)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	
GRF X-axis (Right)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	
Pelvic Obliquity (Left)	Pre	-0.816	9	2.745	0.862
	Post	-0.900	9	2.551	
Pelvic Obliquity (Right)	Pre	1.024	9	2.528	**0.034***
	Post	0.137	9	2.976	
Hip Ab/Adduction (Left)	Pre	-4.146	9	5.098	0.174
	Post	-5.527	9	4.964	
Hip Ab/Adduction (Right)	Pre	-1.613	9	4.481	**0.005***
	Post	-3.047	9	4.961	
Knee Ab/Adduction (Left)	Pre	1.103	9	6.049	0.281
	Post	2.152	9	7.222	
Knee Ab/Adduction (Right)	Pre	1.510	9	7.965	0.180
	Post	3.511	9	9.965	
Ankle Ab/Adduction (Left)	Pre	2.238	9	2.950	0.330
	Post	2.656	9	2.939	
Ankle Ab/Adduction (Right)	Pre	2.543	9	3.447	0.778
	Post	2.674	9	3.334	
GRF Y-axis (Left)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	
GRF Y-axis (Right)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	

Pelvic Rotation (Left)	Pre	-2.799	9	5.991	0.441
	Post	-1.822	9	5.274	
Pelvic Rotation (Right)	Pre	-1.367	9	5.644	0.935
	Post	-1.466	9	5.300	
Hip Rotation (Left)	Pre	-0.187	9	10.051	0.322
	Post	-1.779	9	11.464	
Hip Rotation (Right)	Pre	-0.142	9	9.407	0.272
	Post	1.270	9	10.826	
Knee Rotation (Left)	Pre	6.577	9	10.694	0.788
	Post	7.087	9	9.641	
Knee Rotation (Right)	Pre	3.561	9	11.926	0.081
	Post	0.701	9	13.864	
Ankle Rotation (Left)	Pre	-11.471	9	7.911	0.881
	Post	-11.651	9	9.994	
Ankle Rotation (Right)	Pre	-8.851	9	7.725	0.103
	Post	-7.300	9	9.788	
GRF Z-axis (Left)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	
GRF Z-axis (Right)	Pre	.0000b	9	0.000	1.000
	Post	.0000b	9	0.000	

Appendix Table 2.16.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Heel-Strike (Independent Samples T-test)

		N	Mean	Std. Deviation	sig	P value
Pelvic Tilt (Left)	Active	31	0.04	2.15579	0.939	0.567
	Sedentary	9	-0.40	1.95980		
Pelvic Tilt (Right)	Active	31	-0.26	1.89005	0.793	0.357
	Sedentary	9	-0.87	1.63444		
Hip Flexion/Extension (Left)	Active	31	0.69	4.09706	0.475	0.521
	Sedentary	9	1.80	4.51064		
Hip Flexion/Extension (Right)	Active	31	-0.29	5.02802	0.564	0.495
	Sedentary	9	-1.81	5.91166		
Knee Flexion/Extension (Left)	Active	31	0.59	4.23745	0.450	0.109
	Sedentary	9	2.70	2.98245		
Knee Flexion/Extension (Right)	Active	31	-0.54	3.87100	0.226	0.833
	Sedentary	9	-0.15	4.90538		
Ankle Dorsi/Plantar Flexion (Left)	Active	31	0.04	2.51155	0.258	0.799
	Sedentary	9	0.24	1.92104		
Ankle Dorsi/Plantar Flexion (Right)	Active	31	-0.17	2.70054	0.660	0.429
	Sedentary	9	0.58	2.37129		
GRF X-axis (Left)	Active	31	0.14	0.69481	0.981	0.457
	Sedentary	9	-0.07	0.75571		
GRF X-axis (Right)	Active	31	-0.17	0.64105	0.773	0.277
	Sedentary	9	0.12	0.67622		
Pelvic Obliquity (Left)	Active	31	0.22	1.37215	0.438	0.132
	Sedentary	9	0.92	1.09842		
Pelvic Obliquity (Right)	Active	31	0.19	1.46055	0.500	0.711
	Sedentary	9	0.38	1.24369		
Hip Ab/Adduction (Left)	Active	31	0.05	1.75071	0.828	0.229
	Sedentary	9	0.80	1.52484		
Hip Ab/Adduction (Right)	Active	31	0.02	1.71940	0.644	0.449
	Sedentary	9	0.65	2.18913		
Knee Ab/Adduction (Left)	Active	31	-0.02	1.56230	0.906	0.355
	Sedentary	9	-0.47	1.16763		
Knee Ab/Adduction (Right)	Active	31	0.17	1.51682	0.637	0.341
	Sedentary	9	-0.32	1.24280		
Ankle Ab/Adduction (Left)	Active	31	-0.12	0.92144	0.804	**0.010***
	Sedentary	9	0.75	0.73429		
Ankle Ab/Adduction (Right)	Active	31	-0.28	0.87813	0.039	**0.013***
	Sedentary	9	0.88	1.90771		
GRF Y-axis (Left)	Active	31	-0.41	1.51166	0.505	0.296
	Sedentary	9	0.09	1.14955		
GRF Y-axis (Right)	Active	31	-0.52	1.93459	0.649	0.268

	Sedentary	9	0.27	1.75978		
Pelvic Rotation (Left)	Active	31	0.18	4.16646	0.241	0.363
	Sedentary	9	1.24	2.57615		
Pelvic Rotation (Right)	Active	31	-0.07	3.08338	0.695	0.508
	Sedentary	9	-0.95	3.49699		
Hip Rotation (Left)	Active	31	0.35	6.33948	0.436	0.238
	Sedentary	9	-1.55	3.24803		
Hip Rotation (Right)	Active	31	-1.97	5.36581	0.116	0.057
	Sedentary	9	0.88	3.12933		
Knee Rotation (Left)	Active	31	-1.23	5.22781	0.248	0.171
	Sedentary	9	0.52	2.45490		
Knee Rotation (Right)	Active	31	-0.48	5.85376	0.412	0.697
	Sedentary	9	0.13	3.40737		
Ankle Rotation (Left)	Active	31	0.47	4.18442	0.600	0.088
	Sedentary	9	-1.78	2.98490		
Ankle Rotation (Right)	Active	31	0.81	4.74983	0.952	0.639
	Sedentary	9	0.06	3.94415		
GRF Z-axis (Left)	Active	31	0.48	0.72290	0.537	0.917
	Sedentary	9	0.52	0.88312		
GRF Z-axis (Right)	Active	31	0.38	0.79523	0.815	0.784
	Sedentary	9	0.47	0.88411		

Appendix Table 2.17.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Mid-Stance (Independent Samples T-test).

		N	Mean	Std. Deviation	sig	P value
Pelvic Tilt (Left)	Active	31	-0.08	2.18326	0.945	0.470
	Sedentary	9	-0.61	1.75703		
Pelvic Tilt (Right)	Active	31	-0.34	1.82766	0.730	0.719
	Sedentary	9	-0.60	1.80732		
Hip Flexion/Extension (Left)	Active	31	-0.14	3.25923	0.242	0.312
	Sedentary	9	1.53	4.38507		
Hip Flexion/Extension (Right)	Active	31	-0.16	3.30275	0.300	0.677
	Sedentary	9	-0.83	4.37675		
Knee Flexion/Extension (Left)	Active	31	0.08	2.55572	0.540	**0.019***
	Sedentary	9	3.35	3.30586		
Knee Flexion/Extension (Right)	Active	31	0.36	2.34489	0.933	0.822
	Sedentary	9	0.61	2.98172		
Ankle Dorsi/Plantar Flexion (Left)	Active	31	-0.33	1.76345	0.421	**0.020***
	Sedentary	9	1.13	1.40967		
Ankle Dorsi/Plantar Flexion (Right)	Active	31	-0.08	1.85736	0.739	0.617
	Sedentary	9	0.28	1.87869		
GRF X-axis (Left)	Active	31	0.08	0.50554	0.812	0.423
	Sedentary	9	-0.06	0.44616		
GRF X-axis (Right)	Active	31	-0.13	0.48760	0.515	0.583
	Sedentary	9	-0.04	0.38655		
Pelvic Obliquity (Left)	Active	31	-0.15	1.46987	0.240	0.755
	Sedentary	9	-0.02	0.93995		
Pelvic Obliquity (Right)	Active	31	-0.04	1.09113	0.420	0.560
	Sedentary	9	0.26	1.34649		
Hip Ab/Adduction (Left)	Active	31	-0.12	1.45990	0.266	**0.040***
	Sedentary	9	0.87	1.07572		
Hip Ab/Adduction (Right)	Active	31	-0.01	1.43826	0.067	0.841
	Sedentary	9	0.16	2.32938		
Knee Ab/Adduction (Left)	Active	31	-0.07	0.81004	0.507	0.364
	Sedentary	9	-0.40	0.96099		
Knee Ab/Adduction (Right)	Active	31	0.14	1.03018	0.550	**0.033***
	Sedentary	9	-0.63	0.81532		
Ankle Ab/Adduction (Left)	Active	31	-0.26	1.02723	0.643	**0.030***
	Sedentary	9	0.74	1.09671		
Ankle Ab/Adduction (Right)	Active	31	-0.10	0.84350	0.290	0.078
	Sedentary	9	0.70	1.13831		
GRF Y-axis (Left)	Active	31	-0.03	0.34220	0.119	0.827
	Sedentary	9	-0.05	0.18446		
GRF Y-axis (Right)	Active	31	-0.06	0.37804	0.171	0.275

	Sedentary	9	0.04	0.19341		
Pelvic Rotation (Left)	Active	31	-0.61	3.55297	0.992	0.314
	Sedentary	9	1.07	4.37874		
Pelvic Rotation (Right)	Active	31	-0.55	3.57706	0.348	0.416
	Sedentary	9	-2.00	4.77285		
Hip Rotation (Left)	Active	31	1.08	5.84598	0.435	**0.035***
	Sedentary	9	-1.83	2.42342		
Hip Rotation (Right)	Active	31	-0.71	4.71652	0.080	0.068
	Sedentary	9	1.19	1.64589		
Knee Rotation (Left)	Active	31	-1.88	4.87077	0.901	**0.007***
	Sedentary	9	2.66	3.60289		
Knee Rotation (Right)	Active	31	0.19	4.60905	0.359	0.463
	Sedentary	9	1.04	2.34666		
Ankle Rotation (Left)	Active	31	1.08	4.00094	0.776	**0.008***
	Sedentary	9	-3.12	3.52642		
Ankle Rotation (Right)	Active	31	-0.24	4.79119	0.373	0.825
	Sedentary	9	-0.52	2.66474		
GRF Z-axis (Left)	Active	31	-0.30	0.61436	0.620	0.554
	Sedentary	9	-0.17	0.52235		
GRF Z-axis (Right)	Active	31	-0.21	0.72731	0.581	0.737
	Sedentary	9	-0.12	0.63111		

Appendix Table 2.18.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Weight Transferance (Independent Samples T-test)

		N	Mean	Std. Deviation	sig	P value
Pelvic Tilt (Left)	Active	31	0.08	1.95979	0.599	0.370
	Sedentary	9	-0.64	2.07181		
Pelvic Tilt (Right)	Active	31	-0.13	2.02681	0.635	0.912
	Sedentary	9	-0.20	1.60178		
Hip Flexion/Extension (Left)	Active	31	-0.15	2.67593	0.432	0.974
	Sedentary	9	-0.19	3.32188		
Hip Flexion/Extension (Right)	Active	31	0.05	3.11813	0.498	0.835
	Sedentary	9	0.26	2.44394		
Knee Flexion/Extension (Left)	Active	31	0.44	3.47750	0.578	0.935
	Sedentary	9	0.30	4.56116		
Knee Flexion/Extension (Right)	Active	31	0.50	3.28608	0.383	0.648
	Sedentary	9	1.28	4.66749		
Ankle Dorsi/Plantar Flexion (Left)	Active	31	-0.94	2.73173	0.262	0.345
	Sedentary	9	0.73	4.84329		
Ankle Dorsi/Plantar Flexion (Right)	Active	31	-0.88	1.87544	0.303	0.778
	Sedentary	9	-1.04	1.36914		
GRF X-axis (Left)	Active	31	0.17	0.65133	0.752	0.315
	Sedentary	9	-0.06	0.58605		
GRF X-axis (Right)	Active	31	-0.29	0.80077	0.460	0.399
	Sedentary	9	-0.06	0.64723		
Pelvic Obliquity (Left)	Active	31	-0.35	1.13731	0.414	0.429
	Sedentary	9	-0.63	0.83746		
Pelvic Obliquity (Right)	Active	31	-0.26	1.02600	0.447	0.756
	Sedentary	9	-0.11	1.28318		
Hip Ab/Adduction (Left)	Active	31	-0.67	1.64234	0.833	0.324
	Sedentary	9	0.02	1.78183		
Hip Ab/Adduction (Right)	Active	31	-0.44	1.65697	0.667	0.742
	Sedentary	9	-0.22	1.72554		
Knee Ab/Adduction (Left)	Active	31	0.02	0.63668	0.416	0.836
	Sedentary	9	-0.02	0.44998		
Knee Ab/Adduction (Right)	Active	31	0.09	0.88316	0.974	0.085
	Sedentary	9	-0.61	1.00906		
Ankle Ab/Adduction (Left)	Active	31	-0.38	0.97029	0.175	0.176
	Sedentary	9	0.34	1.38731		
Ankle Ab/Adduction (Right)	Active	31	-0.18	0.82326	0.060	0.204
	Sedentary	9	0.72	1.92178		
GRF Y-axis (Left)	Active	31	0.48	1.67109	0.663	0.222
	Sedentary	9	-0.32	1.64044		
GRF Y-axis (Right)	Active	31	0.37	1.59988	0.786	0.666

	Sedentary	9	0.12	1.45717		
Pelvic Rotation (Left)	Active	31	-1.35	3.43665	0.385	0.593
	Sedentary	9	-0.51	4.21318		
Pelvic Rotation (Right)	Active	31	-0.27	3.13074	0.437	0.495
	Sedentary	9	-1.23	3.74710		
Hip Rotation (Left)	Active	31	0.36	5.77976	0.513	0.134
	Sedentary	9	-1.57	2.13318		
Hip Rotation (Right)	Active	31	-1.94	4.45548	0.073	**0.032***
	Sedentary	9	0.06	1.24595		
Knee Rotation (Left)	Active	31	-1.10	4.80793	0.669	0.247
	Sedentary	9	0.66	3.54977		
Knee Rotation (Right)	Active	31	0.83	6.03409	0.471	0.708
	Sedentary	9	0.27	3.02864		
Ankle Rotation (Left)	Active	31	1.39	3.55652	0.592	0.442
	Sedentary	9	0.11	4.42465		
Ankle Rotation (Right)	Active	31	-0.13	4.88325	0.823	0.717
	Sedentary	9	0.46	4.03067		
GRF Z-axis (Left)	Active	31	-0.03	0.44252	0.020	0.369
	Sedentary	9	-0.22	0.78971		
GRF Z-axis (Right)	Active	31	0.14	0.40817	0.017	0.847
	Sedentary	9	0.10	0.74396		

Appendix Table 2.19.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Toe-off (Independent Samples T-test)

		N	Mean	Std. Deviation	sig	P value
Pelvic Tilt (Left)	Active	31	-0.28	2.11760	0.662	0.335
	Sedentary	9	-1.09	2.11446		
Pelvic Tilt (Right)	Active	31	-0.40	2.05661	0.556	0.832
	Sedentary	9	-0.22	2.17519		
Hip Flexion/Extension (Left)	Active	31	1.36	5.25320	0.112	0.529
	Sedentary	9	-0.28	7.03692		
Hip Flexion/Extension (Right)	Active	31	1.30	5.04260	0.540	0.722
	Sedentary	9	2.09	5.90552		
Knee Flexion/Extension (Left)	Active	31	2.40	10.68294	0.195	0.773
	Sedentary	9	3.82	13.26042		
Knee Flexion/Extension (Right)	Active	31	2.40	10.10112	0.425	0.854
	Sedentary	9	1.71	9.66830		
Ankle Dorsi/Plantar Flexion (Left)	Active	31	-3.46	7.22437	0.336	0.630
	Sedentary	9	-5.02	8.63957		
Ankle Dorsi/Plantar Flexion (Right)	Active	31	-2.70	8.16306	0.203	0.670
	Sedentary	9	-1.06	10.33442		
GRF X-axis (Left)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
GRF X-axis (Right)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
Pelvic Obliquity (Left)	Active	31	-0.78	1.39161	0.887	0.217
	Sedentary	9	-1.52	1.53001		
Pelvic Obliquity (Right)	Active	31	-0.15	1.08597	0.023	0.944
	Sedentary	9	-0.19	1.93217		
Hip Ab/Adduction (Left)	Active	31	-1.50	2.42582	0.303	0.503
	Sedentary	9	-2.26	3.04934		
Hip Ab/Adduction (Right)	Active	31	-0.92	2.41832	0.048	0.653
	Sedentary	9	-0.42	4.25187		
Knee Ab/Adduction (Left)	Active	31	0.36	3.54574	0.157	0.767
	Sedentary	9	0.92	5.12628		
Knee Ab/Adduction (Right)	Active	31	-0.71	3.25552	0.730	0.589
	Sedentary	9	0.05	3.71236		
Ankle Ab/Adduction (Left)	Active	31	-0.30	1.10405	0.180	0.186
	Sedentary	9	0.54	1.65920		
Ankle Ab/Adduction (Right)	Active	31	-0.09	1.26505	0.289	0.225
	Sedentary	9	0.74	1.81059		
GRF Y-axis (Left)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
GRF Y-axis (Right)	Active	31	0.00	.00000a	0.000	1.000

	Sedentary	9	0.00	.00000a		
Pelvic Rotation (Left)	Active	31	-0.93	3.25063	0.672	0.486
	Sedentary	9	0.08	3.83887		
Pelvic Rotation (Right)	Active	31	0.28	4.00649	0.717	0.422
	Sedentary	9	-0.77	3.14869		
Hip Rotation (Left)	Active	31	0.20	4.43544	0.666	0.755
	Sedentary	9	-0.37	4.78355		
Hip Rotation (Right)	Active	31	-2.42	5.67230	0.431	0.118
	Sedentary	9	-0.09	3.05988		
Knee Rotation (Left)	Active	31	-0.71	5.79147	0.936	0.379
	Sedentary	9	1.22	5.54879		
Knee Rotation (Right)	Active	31	1.38	7.29152	0.364	0.397
	Sedentary	9	-0.11	3.43417		
Ankle Rotation (Left)	Active	31	1.38	3.64877	0.453	0.495
	Sedentary	9	0.26	4.36859		
Ankle Rotation (Right)	Active	31	-0.44	6.41027	0.276	0.765
	Sedentary	9	0.07	3.62596		
GRF Z-axis (Left)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
GRF Z-axis (Right)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		

Appendix Table 2.20.: Comparison of change in mean scores of kinematic and kinetic data (post-pre) between Active and Sedentary participants during Mid-Swing (Independent Samples T-test)

		N	Mean	Std. Deviation	sig	P value
Pelvic Tilt (Left)	Active	31	0.11	1.73730	0.951	**0.045***
	Sedentary	9	-1.28	1.64360		
Pelvic Tilt (Right)	Active	31	-0.22	1.83715	0.319	0.781
	Sedentary	9	-0.45	2.17521		
Hip Flexion/Extension (Left)	Active	31	1.43	2.89717	0.051	0.518
	Sedentary	9	0.26	4.99511		
Hip Flexion/Extension (Right)	Active	31	0.59	3.05373	0.359	0.988
	Sedentary	9	0.57	4.10951		
Knee Flexion/Extension (Left)	Active	31	-0.88	13.26429	0.862	0.368
	Sedentary	9	3.12	10.82598		
Knee Flexion/Extension (Right)	Active	31	-1.11	12.06112	0.271	0.689
	Sedentary	9	0.84	12.81231		
Ankle Dorsi/Plantar Flexion (Left)	Active	31	-1.23	3.90950	0.956	0.376
	Sedentary	9	-2.57	3.86799		
Ankle Dorsi/Plantar Flexion (Right)	Active	31	-1.36	3.58188	0.231	0.791
	Sedentary	9	-1.84	4.98593		
GRF X-axis (Left)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
GRF X-axis (Right)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
Pelvic Obliquity (Left)	Active	31	0.00	1.31435	0.588	0.874
	Sedentary	9	-0.08	1.41307		
Pelvic Obliquity (Right)	Active	31	0.40	1.43699	0.296	**0.008***
	Sedentary	9	-0.89	1.03977		
Hip Ab/Adduction (Left)	Active	31	-0.62	1.42346	0.013	0.273
	Sedentary	9	-1.38	2.77698		
Hip Ab/Adduction (Right)	Active	31	-0.44	1.84475	0.139	0.061
	Sedentary	9	-1.43	1.13314		
Knee Ab/Adduction (Left)	Active	31	1.36	2.30016	0.645	0.757
	Sedentary	9	1.05	2.72108		
Knee Ab/Adduction (Right)	Active	31	1.96	3.31687	0.784	0.978
	Sedentary	9	2.00	4.08847		
Ankle Ab/Adduction (Left)	Active	31	-0.28	0.97928	0.296	0.139
	Sedentary	9	0.42	1.20857		
Ankle Ab/Adduction (Right)	Active	31	-0.04	0.74454	0.155	0.726

	Sedentary	9	0.13	1.34999		
GRF Y-axis (Left)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
GRF Y-axis (Right)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
Pelvic Rotation (Left)	Active	31	0.27	3.57982	0.713	0.614
	Sedentary	9	0.98	3.61651		
Pelvic Rotation (Right)	Active	31	1.34	3.31858	0.658	0.293
	Sedentary	9	-0.10	3.50816		
Hip Rotation (Left)	Active	31	-0.11	5.10302	0.984	0.414
	Sedentary	9	-1.59	4.52087		
Hip Rotation (Right)	Active	31	-0.47	6.07301	0.627	0.257
	Sedentary	9	1.41	3.59243		
Knee Rotation (Left)	Active	31	-1.89	3.37170	0.120	0.242
	Sedentary	9	0.51	5.50467		
Knee Rotation (Right)	Active	31	-0.40	6.99654	0.773	0.209
	Sedentary	9	-2.86	4.29236		
Ankle Rotation (Left)	Active	31	1.10	4.74406	0.628	0.385
	Sedentary	9	-0.18	3.49537		
Ankle Rotation (Right)	Active	31	-0.41	4.67350	0.415	0.112
	Sedentary	9	1.55	2.53074		
GRF Z-axis (Left)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		
GRF Z-axis (Right)	Active	31	0.00	.00000a	0.000	1.000
	Sedentary	9	0.00	.00000a		

Appendix Table 2.21: Comparison of all mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Heart Rate	Pre	73.78	40	14.129	**<0.001***
	Post	160.20	40	24.843	
Cadence	Pre	106.23	40	10.717	**0.002***
	Post	110.44	40	10.101	
Limp Index (Left)	Pre	0.98	40	0.091	0.713
	Post	0.98	40	0.051	
Limp Index (Right)	Pre	1.02	40	0.061	0.141
	Post	0.98	40	0.115	
Step Length (Left)	Pre	0.66	40	0.059	0.488
	Post	0.67	40	0.052	
Step Length (Right)	Pre	0.66	40	0.060	0.543
	Post	0.67	40	0.053	
Step Time (Left)	Pre	0.58	40	0.060	**<0.001***
	Post	0.55	40	0.050	
Step Time (Right)	Pre	0.56	40	0.064	0.240
	Post	0.55	40	0.058	
Step Width (Left)	Pre	0.15	40	0.043	0.581
	Post	0.15	40	0.042	
Step Width (Right)	Pre	0.16	40	0.040	0.672
	Post	0.16	40	0.043	
Walking Speed (Left)	Pre	1.17	40	0.161	**0.043***
	Post	1.21	40	0.153	
Walking Speed (Right)	Pre	1.15	40	0.165	**0.024***
	Post	1.20	40	0.149	
Stride Time (Left)	Pre	1.14	40	0.118	**0.023***
	Post	1.10	40	0.103	
Stride Time (Right)	Pre	1.14	40	0.123	**0.002***
	Post	1.09	40	0.103	
Stride Length (Left)	Pre	1.31	40	0.103	0.569
	Post	1.32	40	0.098	
Stride Length (Right)	Pre	1.30	40	0.103	0.971
	Post	1.30	40	0.092	

Appendix Table 2.22: Comparison of Active participants' mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Cadence	Pre	106.30	31	8.817	**0.02***
	Post	109.83	31	9.500	
Limp Index (Left)	Pre	0.98	31	0.090	0.57
	Post	0.98	31	0.050	
Limp Index (Right)	Pre	1.02	31	0.064	0.19
	Post	0.97	31	0.129	
Step Length (Left)	Pre	0.67	31	0.058	0.36
	Post	0.67	31	0.056	
Step Length (Right)	Pre	0.67	31	0.062	0.91
	Post	0.67	31	0.056	
Step Time (Left)	Pre	0.57	31	0.050	**0.00***
	Post	0.55	31	0.044	
Step Time (Right)	Pre	0.56	31	0.052	0.36
	Post	0.55	31	0.061	
Step Width (Left)	Pre	0.16	31	0.043	0.32
	Post	0.16	31	0.043	
Step Width (Right)	Pre	0.16	31	0.040	0.33
	Post	0.17	31	0.044	
Walking Speed (Left)	Pre	1.17	31	0.130	0.06
	Post	1.21	31	0.150	
Walking Speed (Right)	Pre	1.16	31	0.132	0.07
	Post	1.20	31	0.147	
Stride Time (Left)	Pre	1.13	31	0.097	0.08
	Post	1.11	31	0.099	
Stride Time (Right)	Pre	1.14	31	0.100	**0.02***
	Post	1.10	31	0.100	
Stride Length (Left)	Pre	1.31	31	0.099	0.46
	Post	1.33	31	0.105	
Stride Length (Right)	Pre	1.31	31	0.102	0.95
	Post	1.31	31	0.100	

Appendix Table 2.23: Comparison of Sedentary participants' mean pre- and post- Spatio-Temporal Parameters (Paired Samples T test)

		Mean	N	Std. Deviation	P value
Cadence	Pre	105.97	9	16.380	0.06
	Post	112.53	9	12.354	
Limp Index (Left)	Pre	0.98	9	0.100	0.80
	Post	0.98	9	0.056	
Limp Index (Right)	Pre	1.02	9	0.055	0.39
	Post	1.00	9	0.041	
Step Length (Left)	Pre	0.66	9	0.065	0.92
	Post	0.66	9	0.029	
Step Length (Right)	Pre	0.64	9	0.052	0.14
	Post	0.66	9	0.042	
Step Time (Left)	Pre	0.58	9	0.089	0.09
	Post	0.54	9	0.071	
Step Time (Right)	Pre	0.56	9	0.099	0.49
	Post	0.55	9	0.048	
Step Width (Left)	Pre	0.13	9	0.037	0.41
	Post	0.13	9	0.027	
Step Width (Right)	Pre	0.15	9	0.043	0.49
	Post	0.15	9	0.032	
Walking Speed (Left)	Pre	1.16	9	0.251	0.42
	Post	1.21	9	0.172	
Walking Speed (Right)	Pre	1.13	9	0.259	0.21
	Post	1.21	9	0.164	
Stride Time (Left)	Pre	1.15	9	0.181	0.17
	Post	1.09	9	0.119	
Stride Time (Right)	Pre	1.16	9	0.191	**0.04***
	Post	1.07	9	0.117	
Stride Length (Left)	Pre	1.30	9	0.122	0.89
	Post	1.29	9	0.062	
Stride Length (Right)	Pre	1.28	9	0.107	0.88
	Post	1.28	9	0.059	