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The Effect of Backpack Strap Configurations on Gait

A research dissertation presented to the

Faculty of Health Sciences, University of Johannesburg,

as partial fulfilment for the Master's Degree in Technology: Chiropractic

by

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Declaration

I, Claire Michelle Lodge, declare that this dissertation is my own, unaided work. It is being submitted as partial fulfilment of a Master's Degree in Technology, in the programme of Chiropractic, at the University of Johannesburg. It has not been submitted before for any degree or examination at any other University or Technicon.

____

Claire Michelle Lodge

On this day the_______of the month of________________20___.

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Dedication

I dedicate this dissertation to those that have supported me through the long process of this degree and writing of this document. I would firstly like to thank my parents Gary and Caryne Lodge for their everlasting support and motivation, without you and the family I would not be who I am today. I would also like to thank my friends and colleagues for ensuring that I stayed on track and sane. And lastly I would like to thank my life partner James Scoones for being my rock, always there when I needed you.

Thank you to everyone that has helped me on this journey, I hope that in helping me you have received something in return from the universe.

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Abstract

Background

The problem statement identified for this study concerns that to the researcher's knowledge there have been no previous studies on the effect of backpack strap configurations on gait. Thus the present study is one of the first to investigate this topic, which is why the only variable that changes in this study is the strap configuration. The simple design and method of this study makes it easy to replicate and ensures that the data can be analysed with regards to whether the hip and/or chest strap has an effect on gait when compared to the control and traditional backpack conditions.

Aim

This study may aid in understanding how the configuration of backpack straps affects gait at a constant load. This may help provide postulating evidence of change of gait within the strap configurations and may lead to the need for further research on the matter. And additionally the results from this study may help improve backpack designs.

Research methodology

A quantitative, exploratory study was conducted, involving a sample of 50 participants between the ages of 18 and 35. The study was conducted as a single consultation where all the data was recorded by the Zebris FDM Gait Analysis System. The participants were required to walk across the measuring plate for 5 conditions. Namely: Control (no backpack), Traditional (2 shoulder straps), traditional with chest strap, traditional with chest + hip strap and traditional with hip strap. The backpack weight was maintained at approximately 10% body weight (BW) throughout the study. The data was analysed using descriptive statistics to analyse which backpack strap configuration had the most or least effect on gait, when compared to both the control and traditional conditions.

Results

The results of this study have shown that certain backpack strap styles do affect gait more than others. Most of the changes found in the spatiotemporal parameters were found to be statistically insignificant ($p > 0,05$) except for the stride time with regards to the chest + hip strap (p = 0,033), stride length for the hip strap (p = 0,025) and double stance phase for both traditional and chest + hip strap conditions (p = 0,029 and p = 0,039). The overall results of this study show that the chest strap has the most effect on the step width, the stride length increases with 10% BW backpack carriage regardless of strap configuration with the hip strap having the most effect. And finally that the double stance increases with 10% BW backpack carriage.

Conclusion and recommendations

It can be concluded that different backpack strap configurations affect gait in different ways. A summative result shows that the chest and/or hip strap combinations had the most effect The current study subsequently recommended that further research be done on this subject on various populations.

Keywords

Gait, backpack, strap configurations, Zebris FDM, young adults

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CHAPTER ONE: INTRODUCTION

1.1 Problem statement

Backpack carriage is a fairly common task which is adopted for various reasons; students carry textbooks, books, stationary and possibly laptops (Al-Khabbaz, Shimada & Hasegawa, 2008). Thus results in a variety of back pack weight, bag designs and carriage styles that can cause a variety of changes in spatiotemporal gait parameters. These changes can include reduced speed, cadence, step length and increased double support phase and stride duration (Chow, et al., 2005; Singh & Koh, 2009; Wang, Pascoe & Weimar, 2001). This study will focus on young adults between the ages of 18 and 35 years because there seems to be a deficit of research on university attendees. Young adults form a significant portion of backpack users and yet there are not many studies focused on this group (Abaraogu, Ugwa, Nnodim & Ezenwankwo, 2017). Other than studies on children's backpack usage (Chow, et al., 2005; Hong & Cheung, 2003; Singh & Koh, 2009) research seems to be focused on specific adult groups such as soldiers and hikers; which both carry heavier loads for longer periods of time (Pau, Mandaresu, Leban & Nussbaum, 2015; Knapik, Harman & Reynolds, 1996).

There have been no previous studies on the effect of backpack strap configurations on gait to the researchers' knowledge. Thus the present study is one of the first to investigate this topic, which is why the only variable that changes in this study is the strap configuration. The simple design and method of this study makes it easy to replicate and ensures that the data can be analysed with regards to whether the hip and/or chest strap has an effect on gait when compared to the traditional backpack. In this study the gait parameters were recorded using the Zebris FDM gait analysis system which is a validated method of capturing objective data (Donath, Faude, Lichtenstein, Nüesch & Mündermann, 2016).

1.2 Aims

Gait analysis on backpack carriage has been a wide field and will always require more explanation via research. This study may aid in understanding how the configuration of backpack straps affects gait at a constant load. This may help provide postulating evidence of change of gait within the strap configurations and may lead to the need for further research on the matter. And additionally the results from this study may help improve backpack designs.

1.3 Possible outcomes or contribution

This research study can have multiple outcomes with it being an exploratory study which aims to determine how backpack strap configurations have an effect on gait. The results from this study may demonstrate that the design of traditional backpacks or that different strap configurations has an effect on gait. Thus may show a need for backpack design improvement in order to reduce gait and posture changes caused by backpack load carriage; which may reduce the incidence of backpack carriage associated pain/discomfort.

This study may help healthcare practitioners understand how different backpack strap configurations effect gait and thus could be something they educate patients on in order to potentially reduce pain or discomfort caused by backpack carriage.

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CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Chapter two serves to explain some variables that effect backpack carriage such as backpack weight and strap configurations (including strap length). The prevalence of pain due to backpack carriage will also be addressed as this is why this study is relevant to chiropractic and healthcare in general. The gait parameters measured in this study will also be explained in this chapter.

2.2 Pain and Backpack Weight

2.2.1 Effect of backpack weight on pain and posture

Lower back injuries are often difficult to define because the pain may result from trauma to a variety of structures including: spinal disks, ligaments, nerve roots or supporting musculature. Carrying a heavy backpack requires a physical demand and may cause repetitive strains on the body due to the added pressure on joints and ligaments (Hu & Jacobs, 2008). Heavier loads may be a risk factor for back injuries which can possibly be explained by the changes in trunk angle that can stress back muscles and/or structures (Knapik, Harman & Reynolds, 1996; Heuscher, Gilkey, Peel & Kennedy, 2010).

The perception of pain and discomfort increases with increased load of the backpack. A case study of school students conducted by Loewenhardt (2009), showed that 11% of acute injuries involved the back but of those injuries only 13% were from wearing a backpack. It was found that the main reason for the back pain due to the backpack was a load exceeding 17% of the carrier's body weight (BW). Lower back pain is associated with increased backpack load.

Although some studies have shown no significant changes in gait until 15-20% of body weight (Mackie, Stevenson, Reid & Legg, 2005; Abaraogu, Ugwa, Nnodim & Ezenwankwo, 2017) and have thus concluded that young adults maintain gait parameters with a backpack load within 15% of the carrier's BW. Regardless of these findings the limit for the load carriage for this study will be 10% of the participant's BW, to ensure the safety and comfort of the participants. This is based on the recommendation that backpacks should be limited to approximately 10-15% of the carrier's BW (Brackley & Stevenson, 2004; Chow, Kwok, Au-Yang, Holmes, Cheng, Yao & Wong, 2005; Lehnen, 2017). Another study estimates that the maximum weight for safe use of a school backpack should be 10% of body mass because of the time spent carrying the backpack and weight having an effect on postural deviations and back pain appearance (de Paula, Silva & Silva, 2015). This is also supported by research done by Lehnen (2017) that states 10% BW is the safe limit for backpack weight because a person can cope in different positions and still maintain almost normal gait. Subjects failed to maintain normal gait at 20% BW in the study mentioned above.

A study conducted on the effect of backpack weight on gait biomechanics showed that stride frequency, double support time and knee range of motion all increased but maximum hip angle of flexion decreased with a heavier load; showing the body's natural way to increase stability and decrease stress on the lower body, which changes the person's posture. (Harman, Han, Frykman & Pandorf, 2000). Poor posture due to posterior placement of load from backpack may contribute overtime to lower back pain and musculoskeletal complaints. Improper backpack use may further exacerbate these issues and may also cause injuries not related to backpacks to become worse (Dahl, Wang, Popp & Dickin, 2016).

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Other factors that could affect the measurements of this type of study include: physical capability, other physical activities, poor seated posture, and psychosocial aspects. As they affect or contribute to reported pain/discomfort (Mackie et al., 2005). For this reason the main testing procedures throughout all studies of this kind are physiological and biomechanical in nature (e.g. oxygen consumption and gait). In this particular research quantitative information about gait will be collected via measuring both distance (e.g. stride length, step width and step length) and spatio-temporal variables such as stride and step duration, cadence and speed (Harman et al., 2000).

2.2.2 Prevalence of Pain

There is a lack of understanding about the initial onset of lower back pain in young adults according to Heuscher, Gilkey, Peel, & Kennedy (2010). Thus further research is required to determine the assocciation between backpack use and injuries, as well as the factors that may affect this such as load, backpack design and physical characteristics. Most lower back problems or issues can be attributed to cumulative activity rather than a specific aggrevator and thus heavy backpack load carriage is a factor in the multifactorial origin of musculoskeletal symptoms (Hu & Jacobs, 2008). Lower back pain was the most frequent physical health complaint, with an annual prevalence of 29,2% in college students. The most common treatments for lower back pain in college students were self care (42,4%), chiropractic care (12,3%), physical therapy (7,7%) and general practitioners (6.5%) (Heuscher, Gilkey, Peel & Kennedy, 2010).

In children between 11 and 13 years of age 65,5% described the backpack as heavy. The symptoms related to backpack carriage were reported to be: muscle soreness (67,2%), back pain (50,8%), numbness (24,5%) and shoulder pain (14,7%). Along with other associated problems such as functional scoliosis and metatarsalgia (Pascoe, Pascoe, Wang, Shim & Kim, 1997). 35% of adolescents in a study by Al-Khabbaz, Shimada, & Hasegawa (2008), reported lower back musculoskeletal pain, even thoughh the mean backpack weight was 11.7% BW. This is supported by Hong & Cheung (2003), which states that the prevalence of non-specific back pain increases with age, shown by the increase from 10% in preadolescents to 50% in adolescents (15-16 years). Backpack load carriage has been identified as an ergonomic risk factor for the onset of back pain in children and adolescents, with some symptoms possibly lasting into adultood (de Paula, Silva & Silva, 2015). This is due to the heavy nature of backpacks contributing to constant postural changes which can initiate harmful processes in the spine, and may occur sooner than previously thought. Li & Chow (2017), has stated that lower back pain increases in the elderly and people with spinal deformities even with a light backpack.

Around 60% of sttudents enroled in state education in Brazil had a load carried by backpack that was over 10% BW. This increased load exposes the students to an increased risk of spinal injuries (de Paula, Silva & Silva, 2015). Majority of injuries influenced by backpack load carriage involve either the lower extremity or back (Knapik, Harman & Reynolds, 1996). 18% of students reported lower back pain as a symptom in a study by Hu & Jacobs (2008) the students who experienced pain spent less time carrying a backpack and students who experienced discomfort spent on average 3-4 hours a day carrying a backpack. In this study 28% of students reported being uncomfortable while carrying a backpack and 8% of students only reported discomfort depending on the backpack weight, the heavier the backpack the higher the discomfort. The mean backpack weight as a percentage of BW was 6,4% (range of 1,1 – 18,6%).

According to Ramprasad, Alias & Raghuveer (2010), actively carrying a backpack less than 30 minuites daily may decrease the odds of developing back and/or neck pain. Also carrying a backpack higher than 10% BW is accossiated with increased incidence of neck and/or back pain symptoms. This may be explained by the significant increase in peak lumbar spine forces associated with backpack carriage. Even at loads as small as 3% BW the peak compression and sheer forces increase significantly and continued to increase as the backpack load increased (Li & Chow, 2017). A backpack weight of 15% BW has been said to increase peak compressive forces by 26,7%, but sheer forces remained the same. This relates the mechanical loading of the spine as a mechanism of injury (Goh, Thambyah & Bose, 1998). Habitual and prolonged carriage of a backpack with excessive load may then result in lower back pain and possible trauma to the lower extremity (Kinoshita, 1985). An excessive load can be described as 15-20% BW or higher, as this load increases the forces enough to cause significant tissue stress of spinal structures. A factor that is also considered is that discomfort was reported from loads of 10% BW and higher (Devroey, Jonkers, de Becker, Lenaerts & Spaepen, 2007).

2.3 Gait

Kirtley (2006), defined gait as any form of movement sequence characterized by intervals of loading and unloading of the lower extremities, and when referring to bipedal locomotion it is defined as the period between two heel strikes of a certain limb (Levangie & Norkin, 2005). Walking requires full range of motion of the lower spine and both lower limbs and is

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considered the dominant form of locomotion which can be referred to as gait. Chow, et al (2005), noted kinematic changes such as decreased pelvic motion and significantly increased flexion and extension of the hip with increased backpack weight; which all mean a decreased range of motion in the lower body and thus showed changes in gait.

Factors that affect gait include magnitude, placement, duration and frequency of load carriage (Harman et al., 2000), which is why these factors are controlled in this study as best as possible in order to ensure that all/majority of the changes in gait are directly attributable to the various backpack strap configurations.

2.3.1 Definitions

There are two main phases of the gait cycle: stance phase and swing phase. One gait cycle includes activities that occur from an initial point of contact with one lower extremity to the point at which the same extremity contacts the ground again (Levangie & Norkin, 2005). Normal gait is characterised as a rhythmic alternation between propulsive and retropulsive motions of the lower limbs which requires co-ordination, balance, intact kinaesthetic and proprioceptive senses and integrity of lower extremity joints and muscles.
All these factors play a role in ensuring the sequence of activities of the lower limbs; which can be broken down into the following subdivisions for the two phases of gait.

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Stance phase consists of the following sequence (Levangie & Norkin, 2005):

- Heel strike / Initial contact: The instant at which the heel of the leading extremity strikes the ground.
- Foot flat / Loading response: Point at which the foot fully contacts the ground. Continues until the contralateral extremity lifts off the ground at the end of the double-support phase.
- Midstance: Point at which the body weight is directly over the supporting lower extremity. Begins when the contralateral extremity lifts off the ground and continues to a position in which the body has progressed over and ahead of the supporting extremity.

- Heel off / Terminal stance: Point at which the heel of the reference extremity leaves the ground. Period from the end of midstance to a point just prior to initial contact of the contralateral extremity or following heel off of the reference extremity.
- Toe off / Pre-swing: Point at which only the toe of the ipsilateral extremity is in contact with the ground. Period from just following heel off to toe off.

Swing phase consists of the following sequence (Levangie & Norkin, 2005):

- Acceleration / Initial Swing: Begins once the toe of the reference (ipsilateral) extremity leaves the ground and continues until midswing or the point at which the swinging extremity is directly under the body. Continues until maximum knee flexion of the reference extremity occurs.
- Midswing: When the ipsilateral extremity passes directly beneath the body. Encompasses the period immediately following maximum knee flexion and continues until the tibia is in a vertical position.
- Deceleration / Terminal Swing: When the tibia passes beyond the perpendicular and the knee is extending in preparation for heel strike. Period from the point at which the tibia is in the vertical position to a point just prior to initial contact.

Many of the steps in the gait cycle sequence, which has been broken down above, are not measured individually by the Zebris FDM Gait Analysis System. Other variables are measured and recorded, which are then given in the report produced by the system. In order to understand the report one should first understand the variables of gait which are measured by the Zebris FDM Gait Analysis System. Table 2.1 below describes these variables taken from Levangie and Norkin (2005). The variables highlighted in the table below are the selected variables that will be analized for this study.

Table 2.1: Description of spatiotemporal parameters measured by the Zebris FDM Gait Analysis system.

Gait parameters (temporo-spatial variables)	**Definition**
Degree of foot rotation	This represents the angle of foot placement which is found by measuring the angle formed by each foot's line of progression and a line that intersects the centre of the heel and the second metatarsal head. A normal angle usually measures approximately 7˚.

Step length (cm)	Described as the linear distance between two successive points of contact of opposite extremities, i.e. heel strike of one to heel strike of opposite extremity.
Stride length (cm)	The linear distance between two successive events of the gait cycle by the same extremity, i.e. heel strike to heel strike of the same extremity.
Step width (cm)	Described as the linear distance between the midpoint of the heel of one extremity to the midpoint of the heel of the opposite extremity.
Stance phase (%)	Begins when one extremity contacts the ground and continues as long as some portion of the foot is in contact with the ground. Makes up 60% of the gait cycle.
Load response (%)	Point at which the foot is in full contact with the ground. Continues until the opposite extremity lifts off the ground.
Single limb support (%)	The period of stance phase whilst opposite lower extremity is in swing phase. The body weight is directly over the supporting limb and the swing limb passes the support limb.
Pre-swing (%)	Point at which only the toe of the ipsilateral extremity is in contact with the ground. Period from heel off to toe off.
Swing Phase (%)	Begins when the toe of one extremity leaves the ground and ceases just before heel strike or contact of the same extremity. Makes up 40% of the gait cycle.
Double stance phase (%)	When both feet are in contact with the ground at the same time during the gait cycle. One lower extremity is beginning stance phase and the opposite lower extremity is ending stance phase. There are 2 double support periods in one gait cycle.
Stride time/ duration (sec)	The amount of time taken for one stride to be accomplished during one gait cycle.
Step time (sec)	The amount of time spent during one step during the gait cycle.
Cadence (steps/min)	The number of steps taken per minute.
Speed / walking velocity (km/h)	Described as the rate of linear motion (measured in kilometres per hour).

2.3.2 Backpack Effects on Gait

Backpack use may contribute to a variety of postural and biomechanical alterations, such as but not limited to: increased forward trunk flexion, decreased lumbar lordosis, postural sway, decreased velocity and stride length as well as an increased stance and double support phases (Pau, Mandaresu, Leban & Nussbaum, 2015). Although evidence is mixed with regards to these alterations, most load carriage studies have found that spatio-temporal gait parameters remained substantially unchanged during various loading conditions (Devroey, Jonkers, de Becker, Lenaerts & Spaepen, 2007; Pau, Mandaresu, Leban & Nussbaum, 2015; Hong & Cheung, 2003).

A statement by Pau, Mandaresu, Leban & Nussbaum (2015) said that "it may appear that gait alterations may only be substantial and relatively higher loads". Devroey, Jonkers, de Becker, Lenaerts & Spaepen (2007), found that there was an absence of changes in stance, swing, single and double support times, velocity and stride time in college-aged students in the 3 load conditions of his study. Walking pattern including stride, velocity and temporal parameters were not significantly affected by carriage of loads up to 20% in a study by Hong & Cheung (2003). This study questioned whether the backpacks tested were of significant enough weight to induce changes in gait parameters. Ahmad & Barbosa (2019) found no main effect on gait variables for children at school level (aged 7-9 years) with backpack loads of 0 – 15% BW. But said that the childeren walked slower and with a decreased cadence with the backpack brought to school than test bags, this shows that backpack weight is too high. This finding is supported by a study that showed a decrease in velocity and cadance when comparing loaded and unloaded conditions (Li & Chow, 2017).

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Contradicting the above results and discussion are studies done by Pascoe, Pascoe, Wang, Shim & Kim (1997) which showed a significant decrease in stride length, increased stride frequency and cadence with backpack use when compared to the no backpack control; and Wang, Pascoe & Weimar (2001) showed a decrease in average velocity and an 11,3% increase of double support time for loads of 15% BW. The step length and frequency however showed no significant difference between loaded and unloaded conditions for loads as great as 20% and 40% BW. Stride length increased at 10% BW and even more significantly at 20% BW with an increased stride frequency in a study done by Lehnen (2017). This study also found no other significant changes in gait parameters at 10% BW but found that at 20% BW there was an increase in double stance phase with subsequent decease in single stance phase. This can be explained by the fact that by increasing the double stance phase a decrease in mechanical demand on the musculoskeletal system occurs because both feet are in contact with the ground (Lehnen, 2017). An increase in double support and subsequent decrease in single support with increased load was also found in a study by Kinoshita (1985).

Other temporo-spatial gait parameters changes can be explained by a hypothesis by Kinoshita (1985) that states a person will shorten stride length as load increases in order to fascilitate a faster transfer of weight from one foot to another. Thus according to this hypothesis the step length would decrease, which reflects results from a study done by Chow, et al. (2005). These results showed that step length decreased with increased load of 15% body weight.

A proposal from Hong & Cheung (2003) questions that if the walking pace was self determined in a study with heavy loads the participants would prefer to walk at a slower speed with a shorter stride. This proposal is supported by a study showing a velocity decrease with load carriage compared to unloaded condition (Singh & Koh, 2009) and a gradual decrease in velocity with loaded conditions for young adults was noted by Charteris (1998) in a study where participants walked at a self-determined speed.

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Knapik, Harman & Reynolds performed a study in 1996 which showed that forward trunk lean, increased double support phase percentage, decreased pelvic rotation, shorter stride length and concominant increase in stride frequency with loads of 30-40kg. These changes may be attributed to the body's load bearing stratergy implimented in order to maintain a normal walking pattern, which is desireable because it reduces streses on bones and mucles of the lumbosacral region and the lower limb (Knapik, Harman & Reynolds, 1996; Li & Chow, 2017). The forward inclination of the trunk helps to keep the body and body system centre of mass over feet.

Backpack carriage significantly reduces postural stability and causes a disturbance of balance (Li & Chow, 2017; Holewun & Lotens, 1992). This was explained by Singh & Koh, 2009 that load carriage in the form of backpacks shifts the combined centre of mass (COM) of the backpack and body system in the posterior direction, shifting the line of gravity posteriorly closer to the boundary of the base of support (BOS); which is the area covered by the feet (Ramprasad, Alias & Raghuveer, 2010). The forward lean of the trunk tries to restore the COM of the combined backpack and body system to the original location of the COM of the body. Therefore ensuring that the line of gravity passes well within the BOS thus minimising load induced instability and mechanical strain on the musculoskeletal system (Singh & Koh, 2009). Although this sagittal trunk shift may aggravate lower back pain (Ramprasad, Alias & Raghuveer, 2010).

Forward trunk lean was also found in a study for 15% and 20% BW conditions (Singh & Koh, 2009) and studies by Knapik, Harman & Reynolds (1996); Kinoshita (1985); Devroey, Jonkers, de Becker, Lenaerts & Spaepen (2007); Pascoe, Pascoe, Wang, Shim & Kim (1997); Al-Khabbaz, Shimada & Hasegawa (2008). Postural angles measured in a study by Ramprasad, Alias & Raghuveer (2010) showed significant changes in head on neck and head with neck on trunk angles at 10% BW as well as changes in trunk angle and lower limb angles with loads as small as 5% BW. The trunk angle decreased and the lower limb angles increased, meaning a forward inclination of the trunk. Devroey, Jonkers, de Becker, Lenaerts & Spaepen (2007) also found a tendancy to increase head extension as load increased and an increased pelvis range of motion with loads as small as 5% BW. There are also reports that show changes in ankle, hip, trunk and pelvis angles with increased load (Devroey, Jonkers, de Becker, Lenaerts & Spaepen, 2007) and increased knee flexion with heavier loads (Kinoshita, 1985).

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Backward trunk lean was noted for unloaded and 10% BW conditions in a static study conducted by Singh & Koh (2009). As well as a study by Goh, Thambyah & Bose (1998) which showed trunk motion of -8,38° for the unloaded condition and -0.57° for the 15% BW loaded condition. This means that for loads until approximately 15%, the body's load bearing strategy while static is slight trunk extension. This is mainly due to the body's centre of gravity (COG) sitting anterior to the lumbosacral junction in an unloaded position (Motmans, Tomlow & Vissers, 2006). Another possible reason for the 3.43° backward trunk inclination found in a study by Al-Khabbaz, Shimada & Hasegawa (2008) is the type of load used; which is based on the organisation of load in the backpack, e.g. books vs sand.

2.4 Backpack strap configuration

It is understood that there has not yet been a study that analyses and compares the various backpack strap configurations of this particular study. But studies based on unilateral versus bilateral backpack straps have shown significant differences in single leg stance time and pressure, stride length and walking speed (Dahl et al., 2016).

2.4.1 Strap length

One factor that needs to remain constant for each participant is relative strap length. This is because more loose shoulder straps allow a more upright, natural posture than tighter shoulder straps where the backpack is carried higher on the back. Tight straps produce 40% more overall shoulder pressure than loose straps (Mackie, et al., 2005). To ensure consistency in strap length relative to participants body (height, size, etc.) the bottom of the backpack will be situated at the level of the posterior superior iliac spine (PSIS); this will also ensure that the straps (chest and hip straps) are placed relatively the same for each participant. This will be checked for each backpack condition prior to the participant conducting the recording for that condition. According to Singh & Koh (2009) most studies indicated that children experience the least amount of postural deviation when the backpack load is placed lower on the back.

Another reason strap length will be regulated is based on load position. According to Knapik, Harman & Reynolds (1996), a higher placed load has a greater destabilizing effect on posture and can thus effect the gait parameters more. While a lower load initiates more of a forward trunk lean it is more stable, the centre of mass of the backpack is closer to the ground and thus takes more movement to get it over the BOS. This shows that the position of the backpack load influences the efficiency of posterior load carriage. Thoracic load placement resulted in increased pelvis anteversion and hip flexion, meaning an increased lumbar lordosis or lumbar extension. In order to minimise this compensation the backpack load should be placed in the waist or hip level, i.e. lumbar placement; which was the preferred method of load carriage in a study by Devroey, Jonkers, de Becker, Lenaerts & Spaepen (2007).

2.4.2 Hip strap

Other research has shown that the non-use of a hip strap produces 40% greater overall forces than when a hip strap is used. This is because the use of a hip strap decreases the demand on the shoulders by distributing more weight to the hips, lower back and abdominal region. It also prevents relative movement of the backpack which reduces compensatory movement by the participant. According to Mackie, et al. (2004), the loose shoulder strap condition was more effective in decreasing shoulder forces when a hip strap was used. Thus condition four (traditional with hip and chest strap) and five (tradtitional with hip strap) are expected to yield a significantly different result when compared to the other conditions (see 3.6.3 for images). Considering kinematic changes recorded by Chow, et al. (2005) showing decreased pevlic motion and increased flexion and extension motion at the hip during load carriage. More research shows that wearing a hip strap decreases energy expenditure and perceived exertion (Pigman, Sullivan, Leigh & Hosick, 2017).

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Previous studies on the effect of backpacks on gait have concluded that a significant decrease in gait parameters such as stride time and cadence with a 10% body weight traditional backpack; (Abaraogu, Ugwa, Nnodim & Ezenwankwo, 2017; Chow, et al., 2005; Knapik, Harman & Reynolds, 1996). This study will be using the same basis of 10% body weight, but will now be comparing the effects of various strap configurations with the weight remaining constant

It is desirable to reduce load-carriage related injuries, which impair performance and cause discomfort. This has been shown to be achieved by using an appropriately designed backpack with a frame and hip belt; because this setup reduces the load on the shoulders and perceived strain. A backpack with hip belt has been shown to localize discomfort in the mid-trunk and upper legs rather than the lower back and shoulders like other traditional backpacks (Knapik, Harman & Reynolds, 1996; Legg & Mahanty, 1985). A backpack with a frame and hip belt was the most ideal and preferred setup in a study because half the load is suported by the frame and the other by transferring the weight and mechanical stress via the hip strap and not the shoulder straps (Legg & Mahanty, 1985; Pascoe, Pascoe, Wang, Shim & Kim, 1997). With the weight positioned around the waist via a padded belt the forces are distributed over a larger area and thus increases comfort whilst carrying heavier loads (Holewun & Lotens, 1992). According to Pau, Mandaresu, Leban & Nussbaum (2015), the absence of a waist strap may contribute to the adverse effects of backpack carriage.

2.5 Muscle involvement

Erector spinae (ES) and rectus abdominis (RA) muscle control the gross trunk movements and provide general trunk stability (Motmans, Tomlow & Vissers, 2006). Thus these muscles are the ones selected to be tested in most research, results are usually measured via EMG studies. Some studies noted asymmetry between left and right of these muscles which shows failure to stabilize the trunk, this failure may leave the lower back susceptible to injury. When a person stands with no load on back the COG sits anterior to the lumbosacral junction meaning ES muscles are resisting slight forward flexion, and when a load is applied via a backpack the COG shifts posteriorly, thus the muscles are resisting extension and the RA become more active (Motmans, Tomlow & Vissers, 2006). A theory proposed by Goh, Thambyah & Bose (1998), states that instead of increasing abdominal force to maintain upright posture when load is applied or increased, the body leans forward to counter the extension movement caused by the backpack, an thus stability is maintained. This abdominal force was measured to increase by only 2-3% with increased backpack load.

During loaded conditions in a static study the trunk posture assumed a backward inclination to a mean degree of -3° due to the backward shift in COG. This posture is counter balanced by an increase in rectus abdominis (RA) activity measured by EMG; which also progressively and disproportionally increases with increase of backpack load. No significant changes were noted in erector spinae (ES) and lack of change of lower limb muscle activity means that external loads have negotiable effect on lower extremity muscles (Al-Khabbaz, Shimada & Hasegawa, 2008). ES EMG activity of backpack load was also reported to be lower than the unloaded condition in a study by Knapik, Harman & Reynolds (1996); Devroey, Jonkers, de Becker, Lenaerts & Spaepen (2007).

An increase in abdominal activity (rectus abdominis oblique and internal oblique)was noted in the following studies: Devroey, Jonkers, de Becker, Lenaerts & Spaepen (2007); Li & Chow (2017); Al-Khabbaz, Shimada & Hasegawa (2008); Motmans, Tomlow & Vissers (2006); Goh, Thambyah & Bose (1998). Backpack carriage of 10% BW created significant changes in peak EMG results which included a decrease in latissimus dorsi, thoracic ES between unloaded and loaded conditions and lumbar ES significantly decreased with loads of 10% and 15% BW (Li & Chow, 2017). An increase of postural muscle activity to help provide spinal stability, would be expected but is not reflected in the results. This can possibly be explained by the lack of co-contraction of abdominals and trunk extensors, meaning that the load is mostly carried passively (Devroey, Jonkers, de Becker, Lenaerts & Spaepen, 2007).

2.6 Gender influences

In a few studies females had higher reports of neck and/or back pain and were more prone to injuries than males (Ramprasad, Alias & Raghuveer, 2010; Heuscher, Gilkey, Peel & Kennedy, 2010). In a study, females had a shortened stride length and greater stride frequency in the unloaded control condition. And had a decrease in stride length with increased load, while the men experienced no significant gait parameter changes (Knapik, Harman & Reynolds, 1996). Detailed results on gender influences were not commented on in this study as the data was not separeted into gender groups.

2.7 Latest Research and Related Studies

In a narrative review of literature by Suri, Shojaei & Bazrgari (July 2019), the effects of backack carriage on spinal biomechanics was addressed. The weight carried in a backpack has been suggested to play a pathogenic role in the development of lower back pain in children and adolescents. This lower back pain at a younger age has been suggested to play an important initiating role in the development of chronic lower back pain in adulthood (Negrini & Carabolona, 2002). For this and various other reasons the backpack weight of students has been a rising concern for the last 2 decades, because around 90% of children in developed countries use backpacks which exceed the recommended weight limit of 10%

BW. (Al-Khabbaz, Shimada & Hasegawa, 2008; Negrini & Carabolona, 2002; Pascoe, Pascoe, Wang, Shim & Kim, 1997).

According to Shymon, Yaszay, Proudfoot, Donohue & Hargens (2014), 82% of children between the ages of 11 and 14 years attribute their lower back pain to the use of a backpack. The ailments linked to backpack use are not linited to back pain; also included are neck and shoulder pain, numbness or tingling in arms and incorrect postural adaptations. This is why the use of a backpack is considered one of the primary sources of pain in children (Al-Khabbaz, Shimada & Hasegawa, 2008; Chow, et al., 2005; Negrini & Carabolona, 2002; Nemire, 2009; Pascoe, Pascoe, Wang, Shim & Kim, 1997). Also younger students tend to carry heavier loads in a backpack than older students according to Nemire (2009). He also found that of the 55% of students in this study that reported pain or discomfort, 39% indicated the back and 60% reported the shoulders as the primary sources of pain.

Considering the following information from O'Day (2008), vertebral ossification is not complete until the mid 20's. Meaning that there is still a high amount of cartilage in children, which is more vulnerable to shear stress and repetitive trauma. This shows that there is a greater risk for overuse and stress injuries in children when compared to adults; especially considering that the spinal load increases considerably with backpack use (Suri, Shojaei & Bazrgari, 2019). This increase in mechanical demand on the body is a repetitive load stress which adds to the cumulative nature of spinal tissue injuries. This may increase the risk of damage to the structures of the lumbar spine (Mackie & Legg, 2008).

Another study that used imaging, reported that a backpack load caused transient deformation of lumbar disks; specifically L1/2, L4/5 and L5/S1 (Shymon, Yaszay, Proudfoot, Donohue & Hargens, 2014). This study found that even with a backpack weight of 4kg, there was a 13% decrease in anterior disk height of the L5/S1 disk. A possible reason for this anterior diskal compression is the forward trunk inclination seen in various studies and has been reported to be between 3.2° and 19.8° depending on the weight of the load which varied between 5 and 20% BW (Hong & Cheung, 2003; Goodgold & Nielsen, 2003; Ramprasad, Alias & Raghuveer, 2010).

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CHAPTER THREE: METHODOLOGY

3.1 Introduction

The aim of the study was to determine the effect of backpack strap configurations on gait. This may help provide postulating evidence of change of gait within the strap configurations and may lead to the need for further research on the matter.

This chapter serves to describe how participants were selected, the examination procedure, the test conditions/intervention, how the objective data was obtained, as well as the tests selected and used to analyse the data.

3.2 Study Design

Exploratory study which gathered data for many different gait parameters, which were all in different units. Majority of the data was numerical and thus was quantitative data (showed in Appendix A). This study was cross-sectional as it aimed to look at an outline of a demographic group (young adults) with regards to a certain phenomenon, being gait changes with backpack strap configurations.

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3.3 Sample information

The participants were volunteers that were recruited mainly by the advertisements (Appendix B) which were placed around the University of Johannesburg, Doornfontein Campus. The volunteer willingly chose to tear the contact slip off the advertisement and contacted the researcher, then an organised time to meet at the Gait Lab was set. The potential participants were informed that their participation was voluntary and would receive no reward.

The total of 50 participants was selected in order for this study to be able to make general comparisons of trends/statistics and not only direct comparisons between participants. Thus making it more viable.

3.4 Inclusion Criteria

The participants need to have complied with the following in order to participate in this study:

- Between the ages of 18 and 35 years (reasons being the minimum age a person can legally sign the consent form without a guardian is 18 years and to ensure no influence of degenerative changes or chronic diseases the age was capped off at 35 years; (Kelly, Groarke, Butler, Poynton & O'Byrne, 2012)).
- The ability to walk independently, with no aid from an assisted walking device such as crutches or a stick.

3.5 Exclusion Criteria

Participants who presented with the following were not able to partake in this study:

- No recent injury that affected their walking, within 3 months, especially of the lower limb.
- Unable to bear weight on their shoulders for any reason.
- Any known pathology of the back, hip, knee and ankle that directly affected the participants walking. Such as: severe osteoarthritis, any fractures or casts, severe pain, etc.
- Obvious postural deviations, known large leg length discrepancy, musculoskeletal or neurological conditions (such as cerebral palsy, muscular dystrophy)
- There was no weight limit for this study.

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3.6 Research Procedure

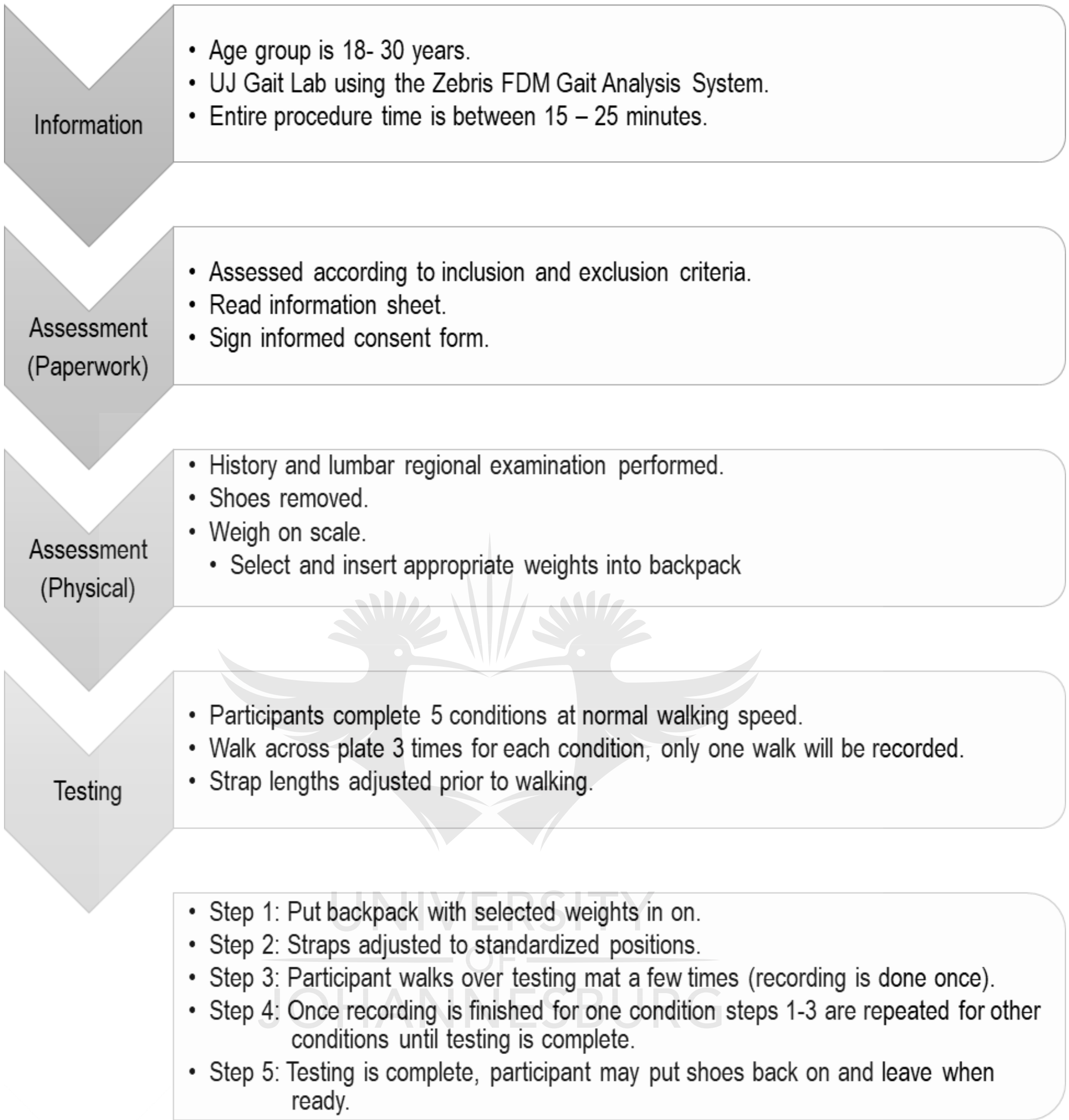

Figure 3.1: Flow diagram indicating the research procedure

3.6.1 Information

The study design of this research was an exploratory single consultation with a total sample number of 50 participants. The study was based at the University of Johannesburg Gait Lab clinic over a period of approximately two months. The evaluation room with the Zebris machine was easily located and private in nature to allow for maximum participant comfort and compliance. The consent process was voluntary in that the volunteer willingly chose to tear the contact slip off the advertisement and contacted the researcher, then an organised time to meet at the Gait Lab was set. Each participant would only need to come in once for the evaluation. This evaluation took between 15 – 25 minutes; in which each participant was required to record five sets of data after completion of the necessary paperwork. The recorded data and information was stored in a safe and secure room in an enclosed cabinet at the University of Johannesburg Chiropractic Day Clinic. Thus information and data remained confidential and only accessible to the researcher, supervisor and participant upon request.

3.6.2 Assessment

Prior to recording the data on the Zebris machine the participant would have been evaluated in accordance to the inclusion and exclusion criteria. Once the researcher had determined the participant would be included in this study the study consent process then began. The process of the testing was explained as well as the consent form. Special emphasis was put on ensuring participant understood the voluntary and confidential nature of the study, and also to ensure they knew that they may choose to no longer partake in the study at any time with no consequences. Once the participant was content that they understood they were given an opportunity to read the information sheet (Appendix C) and sign an informed consent form (Appendix D).

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A history and lumbar spine regional examination was performed in order to eliminate any major lumbar or lower limb pathologies. The participant was then asked to remove their shoes and socks; because the use of footwear alters gait (Vieira, Lehnen, Noll, Rodrigues, de Avelar & da Costa, 2016).

They were then weighed on a scale to establish which weight category they were in. This has been demonstrated by examples in Table 1 of appendix E. Weight categories were rounded to the nearest 5kg to the participant's weight which would be approximately 10% of the participant's body weight, which was decided upon according to the recommended backpack load limit (Chow et al., 2005). The appropriate weight was selected, from various premade weights, and placed in the backpack prior to testing. The backpacks straps length, tension and position were adjusted for each participant, this regulates the backpack and strap position and removes this variable from affecting the results.

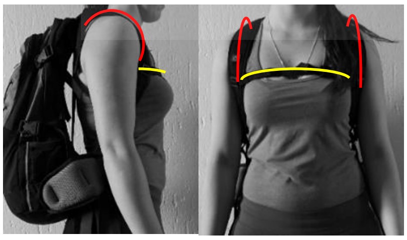
3.6.3 Testing

The effect of the following test conditions on selected gait parameters were evaluated using the Zebris FDM gait analysis system. Pictures provided for reference.

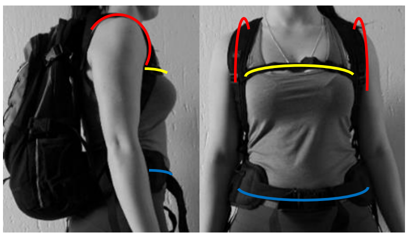
1. Control (no backpack),

2. Traditional backpack (two shoulder straps),

3. Traditional backpack with chest strap



4. Traditional backpack with chest and hip strap



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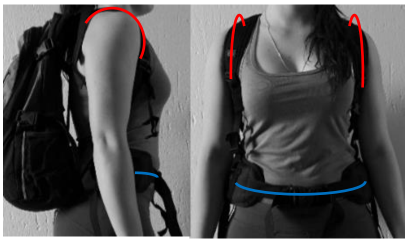
5. Traditional backpack with hip strap.



Each participant had to complete all five of the above condition protocols at a self-determined walking speed; defined as comfortable and normal to each participant. The participants were unaware of when the machine was recording their gait data in order to prevent the participants from consciously changing their gait pattern. This was achieved by making the participants walk across the plate at least 3 times per condition but was only recorded once, which also ensures validity of the reports. The length of the two traditional straps of the backpack were adjusted for each participant so that the bottom of the backpack lies in line with the posterior superior iliac spine (PSIS), which would have been marked on each participant before beginning the recording procedure to speed up the process.

The chest strap for condition three and four was fastened at a medium tension and was placed in line with the sternal notch for each participant to ensure consistency. The hip strap for condition four and five was also fastened at a medium tension and was placed at relatively the same place on each patient as the height of the backpack was regulated for each participant as stated above. This regulates the backpack and strap position which removed this variable from affecting the results. This also made the test easily repeatable and considering that the Zebris gait analysis system has been proven to be valid and reliable (Donath, Faude, Lichtenstein, Nüesch, Mündermann, 2016) this made comparing results from this study to others fairly relative.

3.7 Objective Data

3.7.1 Zebris FDM Gait Analysis System

Data was recorded by a validated method of data collection using the Zebris FDM gait analysis system. This system printed out a report, seen in figure 3.2 (page 25) and appendix

A, containing all values and measurements needed for this study. The variables chosen for this study were: double stance phase, stride length, step width, step time. Each participant would then have five report sheets in their file. Which would be stored safely and in confidentiality. The Zebris FDM Gait Analysis system eliminated any human error on the researcher's behalf which would make the test easily repeatable. In this particular research quantitative information about gait was collected via measuring both distance (e.g. stride length, step width and step length) and spatio-temporal variables such as stride and step duration, cadence and speed (Harman et al, 2000).

Validity

The Zebris FDM gait analysis system and similar equipment has been tested and been shown to have good to excellent validity for walking speed, stride length, cadence and stride time with good to excellent reliability (Donath et al., 2016). This system would be suitable for stance analysis, roll-off analysis and gait analysis; it has robust pressure measurement technology consisting of capacitive, individually calibrated sensors which made gait analysis possible with or without shoes (Zebris Medical GmbH, 2008). Giacomozzi (2010) stated that both static and dynamic pressure tests for gait have very high accuracy.

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Data sheet/report

The Zebris gait report produced by the system was very comprehensive and contains many data variables. Some of them were split into left and right whilst others were a combined total. The parameters chosen for this study were: stride length, stride time, step width and double stance phase. The reason these variables were chosen to be analysed was because previous backpack based studies had found significant changes in these variables and upon an overview of the participants' reports these variables had shown some changes. The reason only a select few variables were selected was because this study was the first on the subject, thus one needed to see if changes were significant enough to warrant further research.

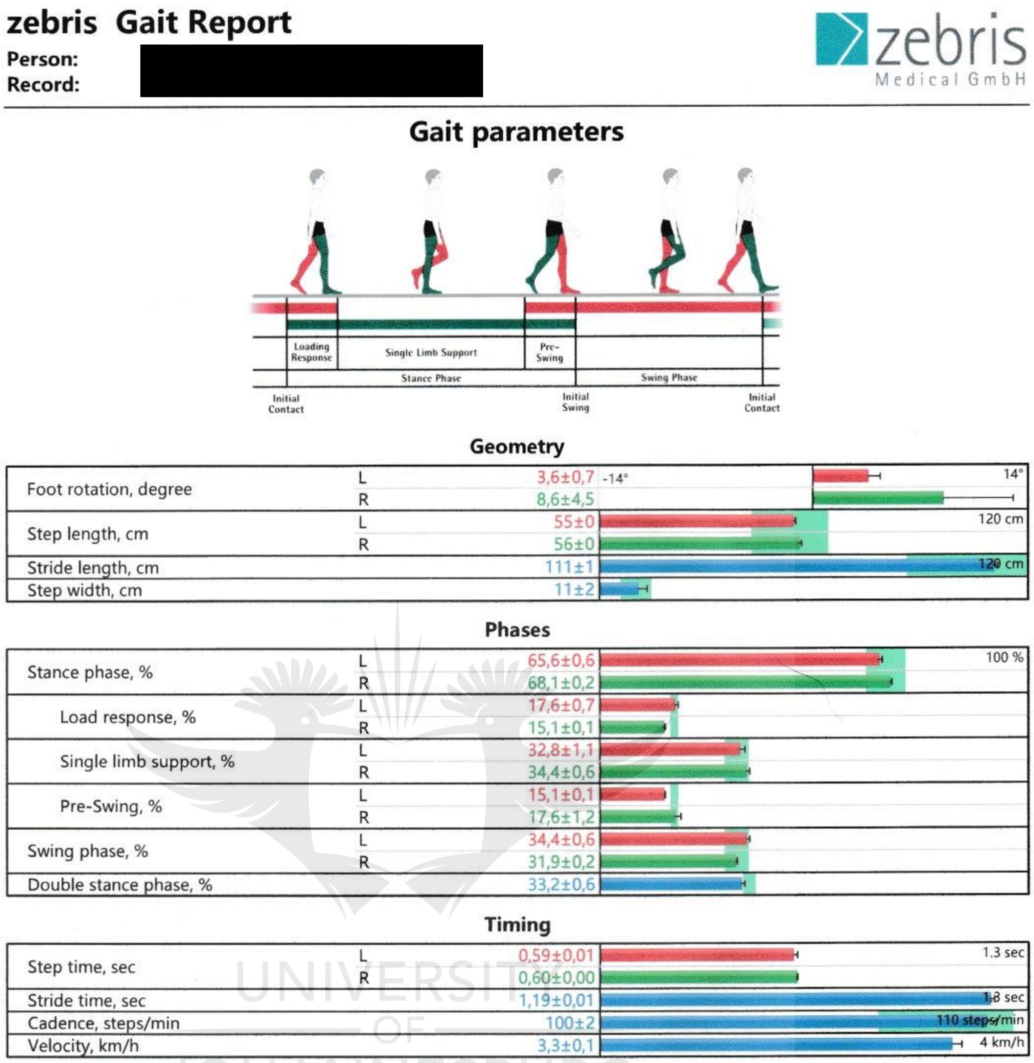

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Figure 3.2: The Zebris Gait Report (Zebris1 Medical GmbH, Germany, 2009).

3.8 Data Analysis

The raw data retrieved from the recordings were analysed by the researcher under the guidance of the supervisor. Comparisons and differences in parameters between conditions and participants were noted and those parameters would be analysed by statkon. Parameters chosen to analyse include: double stance phase, stride length, step width and stride time. Other Zebris parameters were: cadence, foot rotation, step length, step time, stance phase, swing phase, velocity and variability of velocity.

The analysis included descriptive statistics. Kolmogorov–Smirnov Test to check the normality of the variables. Pair Wise comparison tests or Wilcoxon Signed Rank Tests were also performed in order to check statistically significant changes between two time periods or in this study two different conditions.

3.8.1 Kolmogorov-Smirnov Test

This test was used to decide if a sample comes from a population with a specific distribution. It is described as a nonparametric test that compares the cumulative distributions of two data sets. It does not assume that data are sampled from Gaussian distributions (or any other defined distributions). This test will report the maximum difference between the two cumulative distributions, and calculates a P value from that and the sample sizes. Thus the test is fairly robust to outliers (Pallant, 2013).

3.8.4 Wilcoxon Sign Rank Test

The Wilcoxon test, which refers to either the Rank Sum test or the Signed Rank test, is a nonparametric statistical test that compares two paired groups or repeated measurements on a single sample to assess whether their population mean ranks differ. The test essentially calculates the difference between each set of pairs and analyses these differences (Pallant, 2013).

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3.9 Ethical Considerations

All participants that partook in this particular study were requested to read and sign the information and consent form specific to this study. The information and consent forms contained the names of the researcher, purpose of the study and benefits of partaking in the study and participant assessment. The entire procedure was explained to each member including the expected outcome and all procedures they would be required to perform. The form stipulated that each individual's participation would remain confidential regardless of the outcome, as only the doctor/clinician, participant and researcher would be in the testing room. Also that confidentiality was ensured as the participant information would be converted into data and therefore could not be traced back to the individual. The form also stated that the participant's right to privacy was adhered to at all times when compiling the research dissertation.

The participants' files were stored in a safe and secure room in an enclosed cabinet at the University of Johannesburg Chiropractic Day Clinic. The participants were informed that their participation was on a voluntary basis and would be entirely optional with the patient free to discontinue/withdraw from the study at any stage without any consequences. Should the participant have any further questions, they were encouraged to contact the researcher whose contact details were provided. The participants were then required to read and sign the information and consent forms, which signified that they understood all that was required of them for this particular study. Results of the study were made available on request.

With regards to this particular study, there were no risks involved in this study as it merely consisted of recording the participant whilst walking with a backpack on. Benefits involved in participation included: detection of major/minor dysfunctions of the body while doing the history and regional which may have helped the participant seek medical care.

Participants would be referred when necessary and shall not participate in the study if decided upon by researcher, based on exclusion criteria.

Professor Fourie was asked for permission to use students on the campus, even though no treatment will be administered.

This study was approved by the Higher Degrees Committee (HDC) with HDC number: HDC-01-79-2018 (Appendix G) and the Research Ethics Committee of the University of Johannesburg, with the ethics clearance number: REC 241112-035 (Appendix H).

An originality check was completed by submitting the content of the final dissertation via Turnitin (anti-plagiarism software). A report was received and complies with the required policies at UJ (see appendix I).

CHAPTER FOUR: RESULTS

4.1 Introduction

The objective data for this study consisted of gait parameters measured for the following test conditions:

1. Control (no backpack),
2. Traditional backpack (two shoulder straps),
3. Traditional backpack with chest strap, and
4. Traditional backpack with chest and hip strap.
5. Traditional backpack with hip strap.

The gait parameters were measured by the Zebris FDM gait analysis system and a Zebris gait report (Figure 3.2) was created using the WinFDM system.

The objective data was then analysed in the following way:

- Demographic analysis was performed to evaluate the distribution of participants within this study.
- Tests for normality were performed using the Kolmogorov-Smirnov test which is a nonparametric test that compares the cumulative distributions of two data sets. The Wilcoxon Sign Rank Test was performed for comparative data between sets of measurements as it calculates the difference between each set of pairs and analyses these differences.

4.2 Demographic Analysis

The study consisted of 50 participants (N=50). There was only one sample population which were recorded for each condition stated above, thus each participant had 5 gait data reports.

According to demographic analysis described in Table 4.1 below the average age of the sample population was 24 years; with the youngest being 20 years and the oldest being 32 years. The population was more female dominated by 70% of the participants being female.

Table 4.1: Demographic data of sample population.

Average age	24 years
Male participants	15/50 = 30%
Female participants	35/50 = 70%

4.3 Objective Data

The objective data in this study was tested for normality in order to determine whether parametric or non-parametric tests would be used using the Kolmogorov-Smirnov test. If the p-value was greater than 0.05 the data was normally distributed ($p > 0.05$), if however the p-value was less than or equal to 0.05 ($p \leq 0.05$) it was not normally distributed. Parametric tests are generally used to compare data that is normally distributed and non-parametric tests are generally used to compare data that is not normally distributed i.e. there may be random outliers detected within the data.

Although most tests for normality showed that the data was normally distributed, there were outliers detected in some of the data recorded and as a result non-parametric testing proved to be the most effective method to be used in this study. The non-parametric tests that were used for the data analysis in this study were the Kolmogorov-Smirnov Test and the Wilcoxon Sign Rank Test.

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The data from these tests which included the mean values and p-values, which were the main values considered when compiling the results. When looking at the mean value of each condition recorded for each gait parameter there were changes that were noted from condition to condition. These changes will be calculated and discussed below. The changes were calculated when compared to the control condition as well as the traditional condition.

The mean values for each condition were compared to both the control (no backpack) and the traditional backpack (2 shoulder straps only). The control condition values were treated as the normal/baseline for when comparisons are made; which essentially means that these values were the closest to the average gait pattern measured by the Zebris FDM system and was thus the optimal/original gait. This was done as to be able to compare each condition to a standard measurement in order to ascertain which condition had the least and most variation from normal gait. The aim of doing this comparison is to establish which condition affects gait the least, meaning it has the closest mean value to the control. This would show that there is minimal biomechanical adaptation for that condition with regards to that specific variable.

The reason the conditions are then compared to the traditional backpack data is to analyse whether or not the backpack is the cause of the changes found when compared to the control condition or if it is specifically the strap configuration in that condition. This would mean that the traditional condition is now the control or normal value for this comparison. The same principal applies when looking at this data, that the bigger the difference the greater the effect on gait for that variable. Results made from this data may be assumed to be from the direct effect from the strap configurations because neither the position nor the weight of the backpack changed.

The tables below show the differences of the mean for each condition per variable when compared to both the control and traditional conditions. A negative value simply means that the value for that condition was higher than the normal it's being compared to, i.e. an increase. And a positive value difference shows a lower value for the condition than the normal, i.e. a decrease. The positive or negative value of the difference is not taken into consideration as it only indicates an increase or decrease of the variable when compared to the normal. The magnitude of the change is the primary factor taken into consideration for these mean difference comparisons.

The Wilcoxon Sign Rank test calculates the difference between each set of pairs and analyses these differences. In order to analyse this data the Asymp. Sig. (2-tailed) values are used. This value is essentially a p-value for that comparison of 2 conditions. The p-value is given a value which will be a number between 0 and 1. When deciding on the significance of a p-value the cut-off is set at 0,05. This means a small p-value (≤ 0.05) indicates a level of significance whereas a large p-value (> 0.05) indicates that the difference in data is not significant. For this study comparisons to the control and traditional conditions were made again for the same reasons as stated above.

The data taken from the Wilcoxon Sign Rank Test statistics shows three decimal places due to the fact that when comparing the data to a value of 0,05 which has two decimal places. If you round the values up to two decimals it makes this comparison less accurate.

4.3.1 Step width data results

Table 4.2: Showing data collected for step width variable.

A	**Step Width (cm)**				
	Control (x^a)	**Traditional (x^b)**	**Chest strap (x^1)**	**Chest & hip strap (x^2)**	**Hip strap (x^3)**
Std. deviation	3,621	3,289	3,320	3,960	3,325
Mean	12,06	12,14	11,72	11,90	11,92
Compared to x^a		-0,08	0,34	0,16	0,14
Compared to x^b	0,08		0,42	0,24	0,22
P-value for x^a		0,990	0,493	0,526	0,694
P-value for x^b	0,990		0,174	0,556	0,529

Control

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The data collected for the control condition showed a mean value of **12,06cm** (SD ± 3,621). When compared to the traditional condition there was a difference of **0,08cm** and a p-value of **0,990.** This means that this difference of the mean values is not significant ($p > 0.05$).

Traditional

The data collected for the traditional condition showed a mean value of **12,14cm** (SD ± 3,289). When compared to the control condition there was a difference of **-0,08cm** and a p-value of **0,990.** This means that this difference of the mean values is not significant ($p > 0.05$). The negative difference means that the step width increased from the control conditions value.

Chest strap

The data collected for the chest strap condition showed a mean value of **11,72cm** (SD ± 3,320). When compared to the control condition there was a difference of **0,34cm** and a p-value of **0,493.** When compared to the traditional condition there was a difference of **0,42cm** and a p-value of **0,174.** This means that this difference of the mean values is not significant for either comparison ($p > 0.05$). The difference of means data shows that the step width decreased more when compared to the traditional backpack condition than to the control condition, which is shown by the larger difference when compared to the traditional condition.

Chest and hip strap

The data collected for the chest and hip strap condition showed a mean value of **11,90cm** (SD ± 3,960). When compared to the control condition there was a difference of **0,16cm** and a p-value of **0,526.** When compared to the traditional condition there was a difference of **0,24cm** and a p-value of **0,556.** This means that this difference of the mean values is not significant for either comparison ($p > 0.05$). The difference of means data shows that the step width decreased more when compared to the traditional backpack condition than to the control condition, which is shown by the larger difference when compared to the traditional condition.

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Hip strap

The data collected for the hip strap condition showed a mean value of **11,92cm** (SD ± 3,325). When compared to the control condition there was a difference of **0,14cm** and a p-value of **0,694.** When compared to the traditional condition there was a difference of **0,22cm** and a p-value of **0,529.** This means that this difference of the mean values is not significant for either comparison ($p > 0.05$). The difference of means data shows that the step width decreased more when compared to the traditional backpack condition than to the control condition, which is shown by the larger difference when compared to the traditional condition.

Overall

The step width data indicated that the traditional backpack had the least effect on the gait when compared to the control condition by a **decrease of 0,08cm**. The chest strap condition showed the largest effect **0,34cm** while the other two conditions (chest + hip strap and hip strap only) showed similar differences to the control of **0,16cm and 0,14cm respectively.**

The chest strap also had the greatest effect on gait when compared to the traditional condition (**0,42cm**). The other two conditions (chest + hip strap and hip strap only) showed similar differences to the traditional of **0,24cm and 0,22cm respectively.**

This shows that the chest strap decreases step width with a backpack of 10% BW when compared to the both the control (unloaded/ no backpack) and traditional backpack conditions. With the greatest effect being when compared to the traditional condition.

Although these changes were found they were reported of no significance by the Wilcoxon Sign Rank Test.

4.3.2 Stride Time Data Results

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Table 4.3: Showing data collected for stride time variable.

B	**Stride Time (sec)**				
	Control (x^a)	**Traditional (x^b)**	**Chest strap (x^1)**	**Chest & hip strap (x^2)**	**Hip strap (x^3)**
Std. deviation	0,097	0,097	0,088	0,097	0,089
Mean	1,18	1,18	1,18	1,17	1,17
Compared to x^a		0,00	0,00	0,01	0,01
Compared to x^b	0,00		0,00	0,01	0,01
P-value for x^a		0,611	0,838	0,124	0,097
P-value for x^b	0,611		0,321	0,033	0,089

Control

The data collected for the control condition showed a mean value of **1,18sec** (SD ± 0,097). When compared to the traditional condition there was a difference of **0,00sec** and a p-value of **0,611.** This means that this difference of the mean values is not significant (p > 0.05).

Traditional

The data collected for the traditional condition showed a mean value of **1,18sec** (SD ± 0,097). When compared to the control condition there was a difference of **0,00sec** and a p-value of **0,611.** This means that this difference of the mean values is not significant (p > 0.05). No change was noted in the stride time for the traditional condition.

Chest strap

The data collected for the chest strap condition showed a mean value of **1,18sec** (SD ± 0,088). When compared to the control condition there was a difference of **0,00sec** and a p-value of **0,838.** When compared to the traditional condition there was a difference of **0,00sec** and a p-value of **0,321.** This means that this difference of the mean values is not significant for either comparison (p > 0.05). No change was noted in the stride time for both comparisons for the chest strap condition.

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Chest and hip strap

The data collected for the chest and hip strap condition showed a mean value of **1,17sec** (SD ± 0,097). When compared to the control condition there was a difference of **0,01sec** and a p-value of **0,124.** When compared to the traditional condition there was a difference of **0,01sec** and a p-value of **0,033.** This means that this difference of the mean values is not significant for the control comparison (p > 0.05) but is significant when compared to the traditional condition (p ≤ 0,05). The difference of means data shows that the stride time decreased the same when compared to the traditional backpack condition and to the control condition.

Hip strap

The data collected for the hip strap condition showed a mean value of **1,17sec** (SD ± 0,089). When compared to the control condition there was a difference of **0,01sec** and a p-value of **0,097.** When compared to the traditional condition there was a difference of **0,01sec** and a p-value of **0,089.** This means that this difference of the mean values is not significant for either comparison ($p > 0.05$). The difference of means data shows that the stride time decreased the same when compared to the traditional backpack condition and to the control condition.

Overall

The stride time variable data showed that there was minimal change in all conditions when compared to both the control and the traditional conditions. The control, traditional and chest strap conditions mean measurements were exactly the same. While the chest + hip and hip strap only conditions both showed a decrease of **0,01sec** for both comparisons. This reveals that neither backpack carriage of 10% BW nor any strap configuration has much of an effect on the stride time of gait.

The stride time data from the Wilcoxon Sign Rank Test showed that the stride time difference between the traditional and chest + hip strap conditions was of significant value ($p \leq 0,05$). This may be questioned due to the mean data showing only a **0,01sec** difference between the traditional and chest + hip strap conditions.

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4.3.3 Stride Length Data Results

Table 4.4: Showing data collected for stride length variable.

C	Stride Length (cm)				
	Control (x^a)	**Traditional (x^b)**	**Chest strap (x^1)**	**Chest & hip strap (x^2)**	**Hip strap (x^3)**
Std. deviation	11.876	12,616	12,456	12,778	12,297
Mean	119,18	119,30	120,72	120,94	121,42
Compared to x^a		-0,12	-1,54	-1,76	-2,24
Compared to x^b	0,12		-1,42	-1,64	-2,12
P-value for x^a		0,620	0,136	0,077	0,025
P-value for x^b	0,620		0,256	0,271	0,276

Control

The data collected for the control condition showed a mean value of **119,18cm** (SD ± 11,876). When compared to the traditional condition there was a difference of **0,12cm** and a p-value of **0,620.** This means that this difference of the mean values is not significant ($p > 0.05$). The difference means that the stride length decreased when compared to the traditional condition.

Traditional

The data collected for the traditional condition showed a mean value of **119,30cm** (SD ± 12,616). When compared to the control condition there was a difference of **-0,12cm** and a p-value of **0,620.** This means that this difference of the mean values is not significant ($p > 0.05$). The negative difference means that the stride length increased from the control conditions value.

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Chest strap

The data collected for the chest strap condition showed a mean value of **120,72cm** (SD ± 12,456). When compared to the control condition there was a difference of **-1,54cm** and a p-value of **0,136.** When compared to the traditional condition there was a difference of **-1,42cm** and a p-value of **0,256.** This means that this difference of the mean values is not significant for either comparison ($p > 0.05$). The negative differences mean that the stride length increased from the control and traditional conditions' values with the chest strap. The difference of means data shows that the stride length increased more when compared to the control condition than to the traditional backpack condition, which is shown by the larger difference when compared to the control condition.

Chest and hip strap

The data collected for the chest and hip strap condition showed a mean value of **120,94cm** (SD ± 12,778). When compared to the control condition there was a difference of **-1,76cm** and a p-value of **0,077.** When compared to the traditional condition there was a difference of **-1,64cm** and a p-value of **0,271.** This means that this difference of the mean values is not significant for either comparison ($p > 0.05$). The negative differences mean that the stride length increased from the control and traditional conditions' values with the chest strap. The difference of means data shows that the stride length increased more when compared to the control condition than to the traditional backpack condition, which is shown by the larger difference when compared to the control condition.

Hip strap

The data collected for the hip strap condition showed a mean of **121,42cm** (SD ± 12,297). When compared to the control condition there was a difference of **-2,24cm** and a p-value of **0,025.** When compared to the traditional condition there was a difference of **-2,12cm** and a p-value of **0,276.** This means that this difference of the mean values is significant when compared to the control condition ($p \leq 0,05$) but is not significant for the traditional comparison ($p > 0.05$). The negative differences mean that the stride length increased from the control and traditional conditions' values with the chest and hip strap. The difference of means data shows that the stride length increased more when compared to the control condition than to the traditional backpack condition, which is shown by the larger difference when compared to the control condition.

Overall

The mean comparison data for stride length showed that the traditional backpack had the least affect when compared to the control **(-0,12cm).** The hip strap only condition had the greatest difference when compared to both the control and traditional conditions **(-2,24cm and -2,12cm respectively).** This data demonstrates a negative difference throughout comparisons which indicates that with 10% BW backpack carriage there is an increase in stride length regardless of the strap configuration.

The Wilcoxon Sign Rank Test reported a significant difference in stride length between the control and hip strap only condition ($p \leq 0,05$). This may be supported by the difference of means being the greatest between these conditions. This shows that the hip strap had the greatest effect on gait when looking at the stride length which was calculated as **-2,24cm**; which indicates that the stride length increased with the use of the hip strap.

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4.3.4 Double Stance Phase Data Results

Table 4.5: Showing data collected for double stance phase variable.

D	Double Stance Phase (%)				
	Control (x^a)	**Traditional (x^b)**	**Chest strap (x^1)**	**Chest & hip strap (x^2)**	**Hip strap (x^3)**
Std. deviation	3,022	3,724	3,144	3,470	3,608
Mean	29,36	30,44	30,08	30,19	29,77
Compared to x^a		-1,08	-0,72	-0,83	-0,41
Compared to x^b	1,08		0,36	0,25	0,67
P-value for x^a		0,029	0,074	0,039	0,394
P-value for x^b	0,029		0,412	0,485	0,160

For the variable double stance phase the unit is a percentage of the total gait cycle, as calculated by the Zebris FDM Gait Analysis System. This means that the difference of mean calculations are not a percentage difference but a unit difference between conditions.

Control

The data collected for the control condition showed a mean value of **29,36%** (SD ± 3,022). When compared to the traditional condition there was a difference of **1,08%** and a p-value of **0,029.** This means that this difference of the mean values is significant ($p \leq 0,05$). The difference means that the double stance phase decreased when compared the traditional conditions value.

Traditional

The data collected for the traditional condition showed a mean value of **30,44%** (SD ± 3,724). When compared to the control condition there was a difference of **-1,08%** and a p-value of **0,029.** This means that this difference of the mean values is significant ($p \leq 0,05$). The negative difference means that the double stance phase increased from the control conditions value.

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Chest strap

The data collected for the chest strap condition showed a mean value of **30,08%** (SD ± 12,456). When compared to the control condition there was a difference of **-0,72%** and a p-value of **0,074.** When compared to the traditional condition there was a difference of **0,36%** and a p-value of **0,412.** This means that this difference of the mean values is not significant for either comparison ($p > 0.05$). The negative differences mean that the double stance phase increased from the control with the chest strap but decreased when compared to the traditional condition. The difference of means data shows that the double stance phase increased more compared to the control condition than it decreased when compared to the traditional backpack condition, which is shown by the larger difference regardless of positive or negative value.

Chest and hip strap

The data collected for the chest and hip strap condition showed a mean value of **30,19%** (SD ± 3,470). When compared to the control condition there was a difference of **-0,83%** and a p-value of **0,039.** When compared to the traditional condition there was a difference of **0,25%** and a p-value of **0,485.** This means that this difference of the mean values is significant for the comparison to the control ($p \leq 0,05$) but not significant for the comparison to the traditional condition ($p > 0.05$). The negative differences mean that the double stance phase increased from the control with the chest and hip strap but decreased when compared to the traditional condition. The difference of means data shows that the double stance phase increased more compared to the control condition than it decreased when compared to the traditional backpack condition, which is shown by the larger difference regardless of positive or negative value

Hip strap

The data collected for the hip strap condition showed a mean value of **29,77%** (SD ± 3,608). When compared to the control condition there was a difference of **-0,41%** and a p-value of **0,394.** When compared to the traditional condition there was a difference of **0,67%** and a p-value of **0,160.** This means that this difference of the mean values is not significant for either comparison ($p > 0.05$). The negative difference of the mean shows that the double stance phase increased from the control and positive value shows that it decreased when compared to the traditional conditions. The difference of means data shows that the double stance phase decreased more when compared to the traditional backpack condition than to the increase when compared to the traditional condition, which is shown by the larger difference regardless of positive or negative value.

Overall

The mean value comparison data for double stance phase showed that the hip strap only condition had the least effect on gait when compared to the control condition and the traditional had the most effect when compared to the control condition **(-0,41% and -1,08% respectively)**. The chest + hip strap condition showed the least effect when compared to the traditional condition **(0,025%).** The control comparison data shows a trend of negative differences, which indicates that there is an increase in double stance with 10% BW backpack carriage

There were two significant differences found in the double stance from the Wilcoxon Sign Rank Test ($p \leq 0,05$). The comparison between control and traditional conditions were found to be significant. The traditional condition compared to the control condition showed the greatest difference of **-1,08%**, meaning an increase in the double stance phase. The other significant difference that was found by the Wilcoxon Sign Rank Test was between the traditional and chest + hip strap conditions. This comparison showed the smallest difference of mean when compared to the traditional condition (**0,025%**). Thus the significance level was not necessarily reflected or supported by the comparison of means data.

4.4 Comparative non-parametric test combined results

Highlighted in the tables above are all the values of Asymp. Sig. /p-value which are below 0,05, meaning the comparisons between those two conditions showed a significant difference. There are 4 values that are ≤ 0,05 and thus show significance:

- Double stance: Control – traditional (**0,029**)
  Control – chest and hip strap (**0,039**)
- Stride Length: Control – hip strap (**0,025**)
- Stride Time: Traditional – chest and hip strap (**0,033**)

The correlation between these results and the mean differences data have been explained underneath each table above.

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CHAPTER FIVE: DISCUSSION

5.1 Introduction

The aim of this study was to help understand how the configuration of backpack straps affects gait at a constant load of 10% BW. The gait parameters included in the study were: stride time (sec), stride length (cm), step width (cm) and double support (%).

Any statistically significant changes within these gait parameters as seen in chapter four will be discussed and potential theories as seen in chapter two that may explain the changes will be included in this chapter.

5.2 Demographic Data

The study consisted of 50 participants of whom 35 were females and 15 males. The mean age was 24, the maximum age was 32 and the minimum age was 20 (described in Table 4.1). This age cap was decided upon because of the effect of degenerative changes or chronic diseases (Kelly, Groarke, Butler, Poynton, O'Byrne, 2012).

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In a study, females had a shortened stride length and greater stride frequency in the unloaded control condition when compared to their male counterparts. They also had a decrease in stride length with increased load, while the men experienced no significant gait parameter changes (Knapik, Harman & Reynolds, 1996). In this study results like these will not be presented because the data was not grouped by gender. But this study is female dominant thus the mean data may be slightly skewed to the female gait trends found (Knapik, Harman & Reynolds, 1996).

5.3 Objective Data

5.3.1 Step width data

The comparison of mean difference data leads to the finding that the chest strap has the greatest effect on step width when compared to both the control and the traditional conditions. Although the Wilcoxon Sign Rank Test did not find any significance for this data, which means further research on this matter is required to allow researchers to more accurately make conclusions on this subject. Since there have been no other studies on this particular strap configuration, this data cannot be supported or opposed by previous research findings.

A plausible reason why the chest strap affects the step width the most is that the backpack is more secure at the top by the shoulders and therefore the lower aspect of the bag will be more affected by the action of walking. The theory of the researcher was that the left and right sway of the backpack; which naturally occurs due to the sideways swing of the hips during walking; is amplified by the upper portion of the backpack being secured and thus does not sway. This sway is then compensated for by the increase of step width by **0,34cm.** This compensation ensures that the COG of body and backpack remains as close to the middle of the BOS possible.

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5.3.2 Stride time data

The data captured by this study for stride time shows minimal change. The means data for all the conditions was similar, if not the same ranging from a difference of 0,00 – 0,01sec. This finding of no significant difference or change in stride time with 10% BW backpack carriage and various strap configurations is supported by finding from previous studies.

Devroey, Jonkers, de Becker, Lenaerts & Spaepen, (2007); Ahmad & Barbosa, (2019) and Pau, Mandaresu, Leban & Nussbaum, (2015) concluded that there was an absence in changes to stride time amongst other parameters with backpack loads up to 20%. This lead to the questioning of whether substantial changes in gait only occur at higher loads.

Previous studies on the effect of backpacks on gait have found a significant decrease in gait parameters such as stride time and cadence with a 10% body weight traditional backpack; (Abaraogu, Ugwa, Nnodim & Ezenwankwo, 2017; Chow, et al., 2005; Knapik, Harman, & Reynolds, 1996). These findings contradict the findings of this study and those mentioned in the above paragraph.The varying results from backpack gait studies shows a need for further research on the matter with larger sample groups.
One needs to consider that the Wilcoxon Sign Rank test produced a p-value of **0,033**, which indicated a significant difference ($p \leq 0,05$) between the traditional and chest + hip strap condition was **0,01sec**. However the mean data for all the conditions tested were very similar or the same for this variable and the difference of mean data which was indicated as significant was very small. Thus this significance level indicated by the Wilcoxon test is questioned.

5.3.3 Stride length data

A general increase in stride length was noted with backpack carriage of 10% BW with multiple strap configurations. This goes against the theory proposed by Kinoshita (1985) that says as the load increases the subject will shorten their stride in order to facilitate a faster transfer of weight from one foot to another. This theory was shown in the results of studies done with varying loads (Chow, et al., 2005; Knapik, Harman & Reynolds, 1996; Pascoe, Pascoe, Wang, Shim & Kim, 1997). Stride length increased at 10% BW and even more significantly at 20% BW with an increased stride frequency in a study done by Lehnen, 2017. And a few other studies found that the stride length, amongst other variables, remained unchanged with varying loads up to 30% BW (Devroey, Jonkers, de Becker, Lenaerts & Spaepen, 2007; Hong & Cheung, 2003; Pau, Mandaresu, Leban & Nussbaum, 2015; Wang, Pascoe & Weimar, 2001).

The results from this study also indicated that the hip strap had the greatest effect on gait with regards to the stride length variable. As well as a p-value of **0,025** from the Wilcoxon Sign Rank test between the control and hip strap only conditions. Considering kinematic changes recorded by Chow, et al. (2005) which showed decreased pelvic motion and increased flexion and extension motion at the hip during load carriage. This finding does not make sense, as one would expect that the hip strap would limit the hip flexion/extension movement and thus in turn decrease the stride length. But the results show a significant increase of **2,24cm**, which is opposite to the expected result and reasoning above. The reason for the increase in stride length with the hip strap needs further investigation.

The use of the hip strap has been said to increase comfort whilst carrying heavier loads (Holewun & Lotens, 1992). And according to Pau, Mandaresu, Leban & Nussbaum (2015) the absence of a waist strap may contribute to the adverse effects of backpack carriage. This may indicate that the results of the increased stride length may not be a negative finding since it is the most comfortable form of load carriage.

5.3.4 Double stance data

There was a general trend of increased double stance phase percent with backpack carriage regardless of the strap configuration. This shows that even at a backpack load of 10% BW the body's biomechanical adaptation occurs in order to reduce mechanical demand on the musculoskeletal system (Lehnen, 2017). Other studies have found that this adaptation only occurs with a backpack of 15 % BW (Wang, Pascoe & Weimar, 2001). The findings of an increase in double stance phase with subsequent decease in single stance phase have been shown in studies by Kinoshita (1985) and Lehnen (2017). Other studies that have found an increase in double stance phase percent are: Chow, et al. (2005); Harman, Han, Frykman & Pandorf (2000); Knapik, Harman, & Reynolds (1996).

Although there are multiple studies showing similar results to this study there are a few that reported that the double stance phase percent remained unchanged in test cndotions with a backpack of various weights (Devroey, Jonkers, de Becker, Lenaerts & Spaepen, 2007; Hong & Cheung, 2003; Pau, Mandaresu, Leban & Nussbaum, 2015).

Another finding that was noted by the researcher is the conditions that least affected the double stance phase both had the hip strap involved. When compared to the control the hip strap only condition had a difference of **-0,41%** and when compared to the traditional condition the chest + hip strap condition had a difference of **0,025%**. The Wilcoxon Sign Rank test also showed a significant p-value of **0,039** between the control and chest + hip strap conditions as well as a p-value of **0,029** between the control and traditional conditions. The latter significance level shows that the double stance increases the moment a backpack load is applied. The means data shows a difference of **-1,08%** between the control and traditional conditions. This shows that when looking at the strap configurations with regards to double stance phase, it is better to carry the backpack with a hip strap even when combined with other straps.

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CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The aim of this study was to help understand how the configuration of backpack straps affects gait at a constant load of 10% BW. The gait parameters measured by the Zebris FDM gait analysis system which are included in the study were: stride time (sec), stride length (cm), step width (cm) and double support (%).

The results of this study have shown that certain backpack strap styles do affect gait more than others. Most of the changes found in the spatiotemporal parameters were found to be statistically insignificant except for the stride time with regards to the chest + hip strap, stride length for the hip strap and double stance phase for both control and chest + hip strap conditions. The overall results of this study show that the chest strap has the most effect on the step width, the stride length increases with 10% BW backpack carriage regardless of strap configuration with the hip strap having the most effect. And finally that the double stance increases with 10% BW backpack carriage.

This study has shown that different backpack strap configurations affect gait in different ways. A summative result shows that the chest and/or hip strap combinations had the most effect and should then maybe only be used for military and hiking purposes when the backpack load is over 10% BW.

This study may help chiropractors and other healthcare professionals understand how different backpack strap configurations effect gait and thus could be something they educate patients on in order to potentially reduce pain or discomfort caused by backpack carriage.

6.2. Recommendations

The recommendations mentioned below may aid in the improvement of future research studies.

- The population for this study was based on a volunteer convenient sample and was not random. In order to ensure the test population is random advertisements should be placed on other university campuses, in order to maintain the age limit and inclusion criteria.

- Due to the nature of this study the participants may have felt the need to correct their usual posture for the testing process. This effect was thought to have been minimized by the participant being unaware as to when the data was being recorded. But further studies would need to be performed in order to determine if participants altered their usual gait for testing conditions.

- In order to fully understand the effects of the backpack strap configurations more measurements should be taken (both subjective and objective). For example doing a static study and include posture analysis, or use inertial sensors to interpret forces on the backpack and possibly include a muscular EMG reading to better understand how the straps affect muscle activity.

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- The testing could be done more realistically to find out the effect of backpacks for university students/young adults by doing the test with their personal backpack. Calculating the average BW % of the original backpack addresses the problem of overloaded backpacks for students.

- Perform this study as is on different age groups. Such as children, which have a less developed locomotive stability adaptation process. This may yield different results and is the reason why this study may not be able to be applied to other age groups.

- This study is performed on level ground in a gait lab, which does not replicate the environment that young adults experience daily. Thus including video studies of walking up and down stairs with measurements of angles may add helpful data.

- This study does not consider different backpack styles, varying walking speeds or duration of carriage as factors. But have been proven to affect gait, thus modifications of this study can be done to obtain data affected by these or other factors; such as the use of a treadmill to control walking speed.

- The backpack size may have been easier for taller/shorter people to comfortably carry. Thus different sizes of the same style backpack can be used for set height ranges.

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APPENDICES:

APPENDIX A

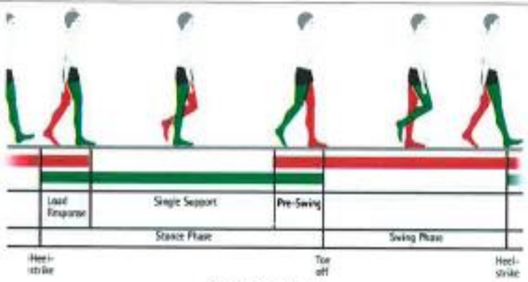
Zebris data sheet example

Project:
Patient:
Record: [redacted]

Zebris Gait Report

zebris

Date of meas.: [redacted]



Parameters

Foot rotation, deg	Left	5.2+/-4.1	
	Right	6.3+/-5.0	
Step width, cm		11+/-5	
Step length, cm	Left	12+/-60	
	Right	22+/-54	
Step time, sec	Left	1.54+/-1.71	
	Right	2.08+/-2.69	
Stance phase, %	Left	36.3+/-25.0	
	Right	35.6+/-24.1	
Load response, %	Left	3.6+/-3.8	
	Right	1.5+/-1.1	
Single support, %	Left	25.5+/-18.1	
	Right	21.8+/-19.4	
Pre-swing, %	Left	7.2+/-6.0	
	Right	5.9+/-4.9	
Swing phase, %	Left	63.7+/-25.0	
	Right	64.4+/-24.1	
Total double support, %		8.6+/-6.9	
Stride length, cm		34+/-103	
Stride time, sec		3.61+/-2.66	
Cadence, strides/min		33+/-23	
Velocity, km/h		0.34+/-1.00	
Variability of velocity, %		293	

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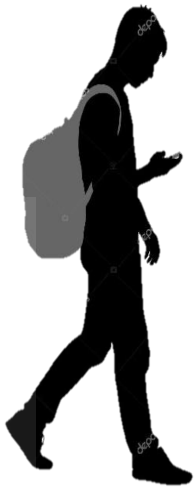
APPENDIX B

Advertisement

The effect of backpack strap configurations on gait.

<u>Would you like to partake in this Chiropractic Master's Research?</u>



All it will take is about **30** minutes of your time.

It is a very simple study, I am evaluating how different Backpack strap setups affect the way a person walks. All you need to do is walk with a backpack on.

The age group for this study is between 18 – 30 years.

If you would like to partake in this study and fit into the above age group please take a tag and contact me.

Ethics clearance no.: REC 241112-035

Claire Lodge – 081 039 8009	Claire Lodge - 081 039 8009	Claire Lodge - 081 039 8009	Claire Lodge - 081 039 8009	Claire Lodge - 081 039 8009	Claire Lodge - 081 039 8009	Claire Lodge – 081 039 8009	Claire Lodge – 081 039 8009	Claire Lodge – 081 039 8009	Claire Lodge – 081 039 8009	Claire Lodge – 081 039 8009	Claire Lodge – 081 039 8009	Claire Lodge – 081 039 8009	Claire Lodge – 081 039 8009	Claire Lodge – 081 039 8009

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APPENDIX C

UNIVERSITY OF JOHANNESBURG

DEPARTMENT OF CHIROPRACTIC

RESEARCH STUDY INFORMATION LETTER

Date:___________________

Good Day,

My name is Claire Lodge I would like to invite you to participate in a research study on the effect of backpack strap styles on immediate gait.

Before you decide on whether to participate, I would like to explain to you why the research is being done and what it will involve for you. I will go through the information letter with you and answer any questions you have. This study should take about 20 to 30 minutes. The study is part of a research project being completed as a requirement for an MTech Degree in Chiropractic through the University of Johannesburg.

The purpose of this study is to gather evidence to determine the effect of backpack strap configurations/setups on gait in young adults (age 18-30 years) by looking at gait parameters using the Zebris FDM gait analysis system. Gait is described as a person's manner of walking and thus the Zebris machine measures different things as you walk on the testing mat.

Below, I have compiled a set of questions and answers that I believe will assist you in understanding the relevant details of participation in this research study. Please read through these. If you have any further questions I will be happy to answer them for you.

Do I have to take part? No, you don't have to. It is up to you to decide to participate in the study. To volunteer you willingly choose to tear the contact slip off the advertisement. After tearing the contact number off and contacting me we will meet at the Gait Lab at organised a time to meet. I will describe the study and go through this information sheet. If you agree to take part, I will then ask you to sign a consent form. You may also choose to no longer partake in the study at any time with no consequences.

What exactly will I be expected to do if I agree to participate? The process of partaking in this research study is voluntary and you may withdraw from the study at any time if you wish to do so. You will need to be measured walking with five different backpack setups at a self-determined walking speed; defined as comfortable and normal by yourself. 1. Control (no backpack), 2. Traditional backpack (two shoulder straps), 3. Traditional backpack with chest strap, and4. Traditional backpack with chest and hip strap. 5. Traditional backpack with hip strap. Analysis of this data will show whether or not various backpack strap configurations/setups have an effect on gait. Step-by-step process will go as follows:

- Step 1: Put backpack with selected weights in on.
- Step 2: Straps adjusted to standardized positions.
- Step 3: You will walk over testing mat a few times (recording is done once).
- Step 4: Once recording is finished for one condition steps 1-3 are repeated for other conditions until testing is complete.
- Step 5: Testing is complete, you may put shoes back on and leave when ready.

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What will happen if I want to withdraw from the study? If you decide to participate, you are free to withdraw your consent at any time without giving a reason and without any consequences. If you wish to withdraw your consent, you should inform me as soon as possible.

If I choose to participate, will there be any expenses for me, or payment due to me: You will not be paid to participate in this study nor is there any expense on your behalf.

Risks involved in participation: There are no risks involved in this study as it merely consists of recording you whilst walking with five different backpack setups on.

Benefits involved in participation: Detection of major/minor dysfunctions of the body while doing the history and regional which may help you seek medical care.

Will my taking part in this study be confidential? Yes, confidentiality means that your personal details and information shall not be shared. As a result, it will not be possible for anyone to know about your participation without your consent.

What will happen to the results of the research study? The results will be written into a research report that will be assessed. In some cases, results may also be published in a scientific journal. In either case, you will not be identifiable in any documents, reports or publications. You will be given access to the study results if you would like to see them, by contacting me.

Who is organising and funding the study? The study is being organised by me, under the guidance of my research supervisor at the Department of Chiropractic in the University of Johannesburg. This study has not received any funding.

Who has reviewed and approved this study? Before this study was allowed to start, it was reviewed in order to protect your interests. This review was done first by the Department of Chiropractic, and then secondly by the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg. In both cases, the study was approved.

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What if there is a problem? If you have any concerns or complaints about this research study, its procedures or risks and benefits, you should ask me. You should contact me at any time if you feel you have any concerns about being a part of this study. My contact details are:

Claire Lodge
0734977133
claireldg@gmail.com

You may also contact my research supervisor:
Dr M Moodley
mmoodley@uj.ac.z

If you feel that any questions or complaints regarding your participation in this study have not been dealt with adequately, you may contact the Chairperson of the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg:

Prof. Christopher Stein
Tel: 011 559-6564
Email: cstein@uj.ac.za

Further information and contact details: Should you wish to have more specific information about this research project information, have any questions, concerns or complaints about this research study, its procedures, risks and benefits, you should communicate with me using any of the contact details given above.

Researcher:
Claire Lodge

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APPENDIX D

DEPARTMENT OF CHIROPRACTIC

RESEARCH CONSENT FORM

The Effect of Backpack Strap Styles on Gait

Please initial each box below:

☐ I confirm that I have read and understand the information letter dated ______________ for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

☐ I understand that my participation is voluntary and that I am free to withdraw from this study at any time without giving any reason and without any consequences to me.

☐ I agree to take part in the above study.

________________________	________________________	_________________
Name of Participant	Signature of Participant	Date
________________________	________________________	_________________
Name of Researcher	Signature of Researcher	Data

APPENDIX E

There is no weight limit for this study. Table demonstrates three different examples of categorising a participant's weight.

Table 1: Weight of participant's and category vs weight in backpack, only showing three random examples.

Weight of Participant	Weight category	Approximate 10% body weight in backpack	Weights placed in bag
54 kg	50-55 kg	5.5 kg	2.5kg + 2.5kg + 0.5kg
68 kg	65-70 kg	7 kg	2.5kg + 2.5kg + 2kg
86 kg	85-90 kg	9 kg	2.5kg + 2.5kg + 2kg + 2kg

Pictures below showing the making of the weights by researcher. Each weight was double bagged to ensure no loss of moisture or sand which would decrease/change the weight from the original weight when produced. Weights were made from sand in flat bags in order for ease of use and to ensure even weight distribution and minimal shifting of weight in the bag.

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The following weights were made and represent the following weight:

2 × 2.5kg	=	25kg each
2 × 2kg	=	20kg each
2 × 1kg	=	10kg each
1 × 0.5kg	=	5kg



Images taken by researcher

APPENDIX F

Backpack testing conditions (pictures taken by researcher with consent)

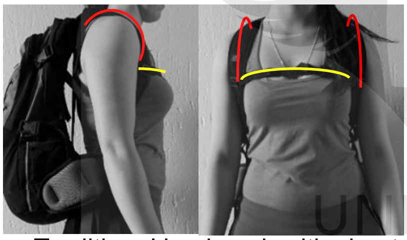
1. Control (no backpack),

2. Traditional backpack (two shoulder straps),

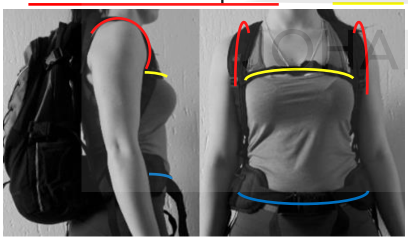
   Bottom of backpack at level of PSIS.

3. Traditional backpack with chest strap,

   Fastened at medium tension in line with sternal notch.

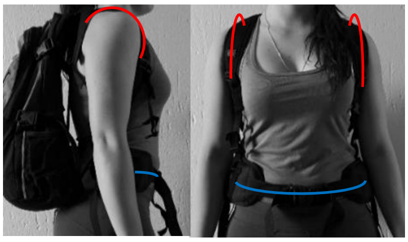


4. Traditional backpack with chest and hip strap



5. Traditional backpack with hip strap.

   Fastened at medium tension.



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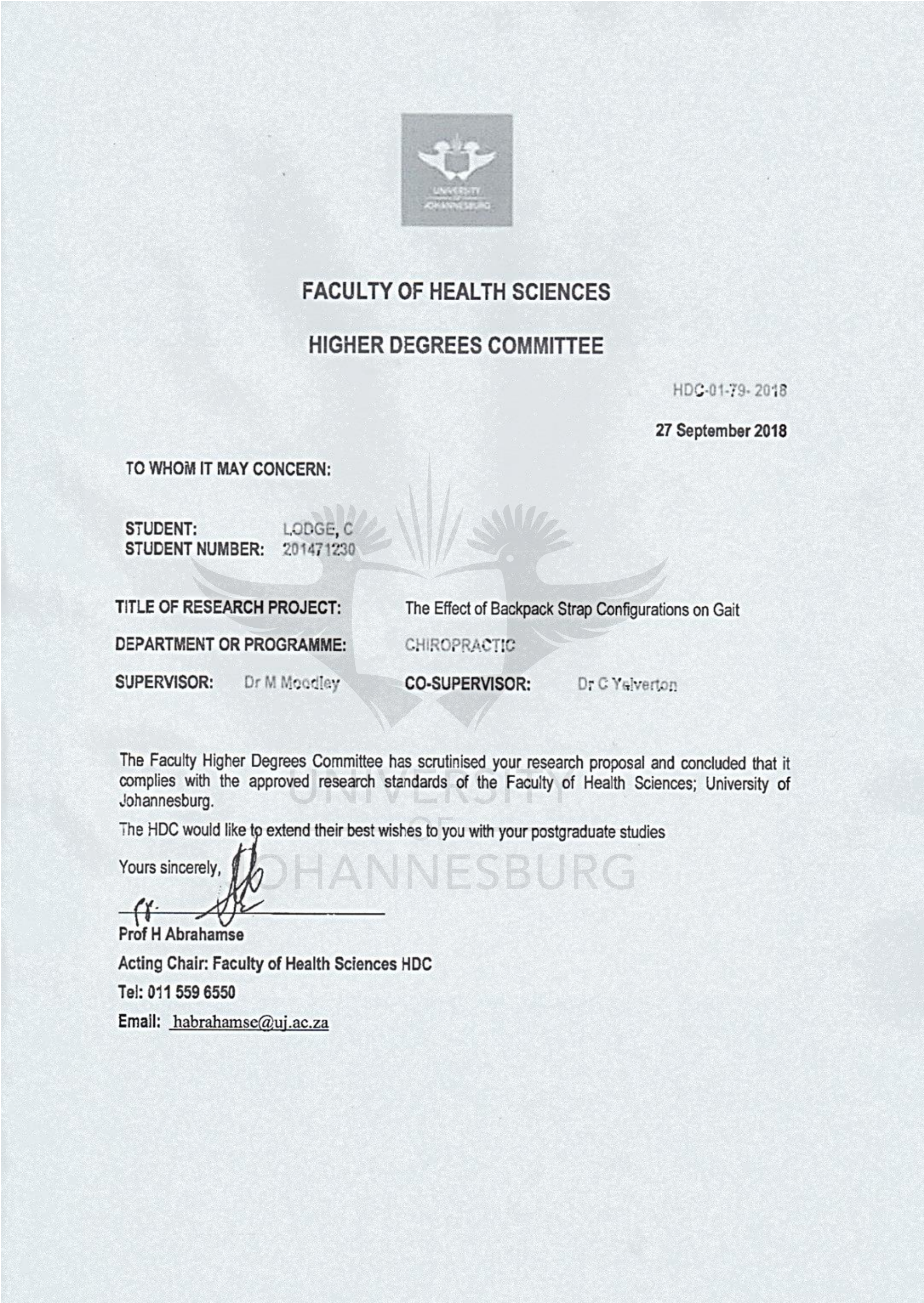
APPENDIX G

Higher Decrees Committee approval letter



FACULTY OF HEALTH SCIENCES

HIGHER DEGREES COMMITTEE

HDC-01-79- 2018

27 September 2018

TO WHOM IT MAY CONCERN:

STUDENT: LODGE, C
STUDENT NUMBER: 201471230

TITLE OF RESEARCH PROJECT: The Effect of Backpack Strap Configurations on Gait

DEPARTMENT OR PROGRAMME: CHIROPRACTIC

SUPERVISOR: Dr M Moodley **CO-SUPERVISOR:** Dr C Yelverton

The Faculty Higher Degrees Committee has scrutinised your research proposal and concluded that it complies with the approved research standards of the Faculty of Health Sciences; University of Johannesburg.

The HDC would like to extend their best wishes to you with your postgraduate studies

Yours sincerely,

Prof H Abrahamse
Acting Chair: Faculty of Health Sciences HDC
Tel: 011 559 6550
Email: habrahamse@uj.ac.za

APPENDIX H

Ethical Clearance Letter

FACULTY OF HEALTH SCIENCES
RESEARCH ETHICS COMMITTEE

NHREC Registration: REC 241112-035

ETHICAL CLEARANCE LETTER
(RECX 2.0)

Student/Researcher Name	Lodge, C	Student Number	201471230
Supervisor Name	Dr M Moodley	Co-Supervisor Name	Dr C Yelverton
Department	Chiropractic		
Qualification	367		
Research Title	The Effect of Backpack Strap Configurations on Gait		
Date	3 December 2018	Clearance Number	**REC-01-170-2018**

Approval of the research proposal with details given above is granted, subject to any conditions under 1 below, and is valid until 31 January 2019.

1. Conditions:
None

2. Renewal:
It is required that this ethical clearance is renewed annually, within two weeks of the date indicated above. Renewal must be done using the Ethical Clearance Renewal Form (REC 10.0), to be completed and submitted to the Faculty Administration office. *See Section 12 of the REC Standard Operating Procedures.*

3. Amendments:
Any envisaged amendments to the research proposal that has been granted ethical clearance must be submitted to the REC using the Research Proposal Amendment Application Form (REC 8.0) prior to the research being amended. Amendments to research may only be carried out once a new ethical clearance letter is issued. *See Section 13 of the REC Standard Operating Procedures.*

4. Adverse Events, Deviations or Non-compliance:
Adverse events, research proposal deviations or non-compliance must be reported within the stipulated time-frames using the Adverse Event Reporting Form (REC 9.0). *See Section 14 of the REC Standard Operating Procedures.*

The REC wishes you all the best for your studies.

Yours sincerely,

Prof. Christopher Stein
Chairperson: REC
Tel: 011 559 6564
Email: cstein@uj.ac.za

RECX 2.0 – Faculty of Health Sciences
Research Ethics Committee

Secretariat: Ms Raihaanah Pieterse
Tel: 011 559 6073 email: rpieterse@uj.ac.za

APPENDIX I

Turnitin originality report

The Effect of Backpack Strap Configurations on Gait

ORIGINALITY REPORT

9%	7%	4%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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2	documents.mx Internet Source	1%
3	Submitted to Napier University Student Paper	1%
4	Tarkeshwar Singh, Michael Koh. "Effects of backpack load position on spatiotemporal parameters and trunk forward lean", Gait & Posture, 2009 Publication	1%
5	Cazmon Suri, Iman Shojaei, Babak Bazrgari. "Effects of School Backpacks on Spine Biomechanics During Daily Activities: A Narrative Review of Literature", Human Factors: The Journal of the Human Factors and Ergonomics Society, 2019 Publication	1%
6	Submitted to Institute of Technology, Sligo Student Paper	1%

7	Submitted to University of Johannsburg Student Paper	1%

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Exclude bibliography	On		

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