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The Effect of Golf Bag Load Carriage on Human Postural Control

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An Honors Thesis submitted in partial fulfillment of the requirements for Honors in the *Department of Health Sciences and Kinesiology*.

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ABSTRACT

Golf is a popular sport for all age groups, and the golf swing is one of the hardest swings to master. It takes balance and trunk stability in order to achieve desired results. Carrying a golf bag for the standard 18-holes may decrease stability and balance from fatigue and lead to injury. The purpose of this study is to examine the effects of different methods of golf bag carriage on balance. Three participants consisting of male and female college-aged individuals (18-30) with golfing experience in the last six months and no current signs of cardiovascular, metabolic, or musculoskeletal disease were observed carrying different golf bag conditions for six miles. Each participant performed under one of the five conditions for each trial. The conditions include 1) no golf bag 2) single strap golf bag 3) double strap bag worn above the sacrum 4) double strap golf bag worn below the sacrum 5) golf bag on a pushcart. Balance was then tested after every .5 mile with 3 trials with: eyes open standing on the BTrackS (San Diego, CA, USA), eyes closed standing on the force plate, eyes open standing on the AIREX Balance Pad (Power Systems Inc., Knoxville, TN, USA) positioned on the force plate, and eyes closed on the AIREX Balance Pad positioned on the force plate. Balance was quantified by the center of pressure and the root mean square of body sway. There was a significant difference between eyes open firm condition ($F(6,12) = 3.04$, $p = 0.048$, $\eta^2 = 0.603$) and the eyes open foam pad condition ($F(6,12) = 5.26$, $p = 0.007$, $\eta^2 = 0.725$). The results suggest that balance decreased over the duration of the 6 miles, regardless of the load-carriage condition.

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CHAPTER I

INTRODUCTION

Golf is a popular sport with participation from all age groups. There are many physical benefits from playing golf such as improved aerobic fitness and trunk muscular strength. This is because there are long bouts of walking in a normal 18-hole game totaling about 6 miles of uneven surfaces (Ikeda, Cooper, Gulick, & Nguyen, 2008). Not only is there a lot of walking but carrying a golf bag over this long distance may affect performance in the game.

The golf swing is known for its complexity because of the technique it requires in order to be accurate. For a successful outcome, golfers must maintain balance and posture (Maddalozzo, 1987). There are two types of balance that are important in golf. These types of balance are static and dynamic. Static balance is being able to maintain a base of support with little to no movement. Dynamic balance is the ability to perform a task while maintaining a stable position or the ability to maintain balance on an uneven surface (Hyrsomallis, 2011). Dynamic balance is important in the weight shift of a golf swing, while static balance is seen in the long duration of walking. Balance may be harder to maintain with the addition of golf bag load carriage (Ikeda, Cooper, Gulick, & Nguyen, 2008).

The effect of load carriage on metabolic costs and biomechanics has been studied widely on participants such as military personnel and students. Placement of load carriages has also been studied with conditions such as asymmetric loads and symmetric loads, as well as loads placed high on the back and loads placed low on the back. Even though there are many studies on load carriage, there is a lack in research of load carriage in golf and how different methods of golf-bag load carriage affects balance. This study investigates four different methods of golf bag carriage.

The purpose of this study is to examine the effects of different methods of golf bag carriage on balance. These conditions of golf bag carriage include single strap, double strap above the sacrum, double strap below the sacrum, pushcart, and no load. Balance will be measured by center of pressure, sway velocity, and RMS sway. The null hypothesis is that load carriage does not influence balance.

CHAPTER II

REVIEW OF LITERATURE

Back problems and injury from load carrying is becoming more of a concern. These injuries can be seen with school children and occupations that must carry heavy loads such as military personnel and firefighters (Negrini, S., & Negrini, A. 2007) (Atwells et al. 2006). Not only does the weight of the load have an effect on risk of injury, but placement of the load also plays a part, as well if the load is symmetric or asymmetric. Golf is a popular sport that is expensive to play, but requires skill to perfect the swing. Balance, flexibility, and strength are needed to be consistent and achieve maximum distance (Sell, Tsai, Smoliga, Myers, & Lephart, 2007). A mechanical overview of a golf swing will be discussed in order to understand the elements that are needed to be successful. There will be an explanation of why balance is important in this leisure and sport activity to provide an understanding of why different types of loading of golf bags is important.

Load Carriage

Load carriage causes physiological strain on the body. Holewijn (1990) analyzed the physiological effects on 4 young men of carrying different amounts of loads with different speeds on a treadmill. The four categories that were investigated included metabolic (oxygen uptake), cardiovascular (heart rate), muscular (EMG activity), and amount of pressure on the skin caused by shoulder straps. Heart rate increased when standing still while wearing a backpack. He also found that the standing oxygen uptake was not influenced, but heart rate and oxygen uptake were significantly influenced while walking regardless of the amount of load applied. Pressure on the skin was the limiting factor when a waist belt did not relive this pressure (Holewijn, 1990).

Many occupations must carry heavy loads such as military personnel, firefighters, and golfers. Postural control and gait with load carriage is a growing concern. Military personnel must carry heavy loads while marching as a component of training Atwells et al. (2006) analyzed 20 male soldiers by using a 3-D motion analysis system to detect changes in posture and gait caused by increasing load in military load carriage system. The different conditions for this study included 8 kg, 16 kg, 40 kg, and 50 kg representing different types of military loads. Ankle, knee, femur, trunk, and craniovertebral angles were made during self-paced walking. It was found that the knee and femur range of motion increased with load and that the trunk flexed forward. This counterbalance necessary with load is associated with injury and muscle strains (Atwells et al. 2006).

The increase of external loads could also lead to loss of balance and a greater fall risk. Qu & Nussbaum (2009) examined the effects of external loads on balance during upright stance. To do this, 12 young, healthy participants (5 female and 7 male) were studied under different combinations of mass (based on a percentage of their individual body mass) and height (based on whole-body center of mass). The mass of the load was increased by placing small silver cylinders in the pockets of the packs. Their center of pressure was measured in a time series, and participants were instructed to stand as still as possible with their eyes open for 90 seconds while standing on a force plate. Fifteen trials were done with two minutes of rest in between each trial. As loads increased, the anterior-posterior mean velocity and the mediolateral RMS also increased. It was found that the application of larger loads and loads superior to the whole-body center of mass leads to less postural control. Furthermore, these types of external loads increase the risk of loss of balance and falls (Qu & Nussbaum, 2009).

Stuempfle, Drury, and Wilson (2004), studied the physiological effects of load position in an internal frame backpack. The variables measured in this study included oxygen consumption, heart rate, respiratory exchange ratio, respiratory rate, minute ventilation, and rate of perceived exertion. Participants that included ten females of college age, walked on a treadmill for ten minutes carrying a load that consisted of 25% of their body weight. Loads were placed in a high, central, or low position. The high position was approximate to the thoracic vertebrae 1-6. Central position was at thoracic vertebrae 7-12, and low position was at lumbar vertebrae 1-5. For 5 minutes, participants warmed up on the treadmill at 4.8 km/hr with 0% grade without carrying a load. They then stretched with a 10 second hold consisting of quadriceps, hamstrings, and lower back. Participants were then given a load under one of the three conditions and walked at 3.2 km/hr at 0% grade for one minute followed by 5.1 km/hr for 9 minutes. Measurements were taken at the final 2 minutes of the protocol when participants were in a steady state. Oxygen consumption, minute ventilation, and rate of perceived exertion was significantly lower. This means that load placement high up on the back was the most energy efficient and could help reduce injury. Load placement should be considered in the design and loading of backpacks (Stuempfle et al. 2004).

Not only does the weight and placement of the load have an impact on body mechanics and metabolic cost, but whether the load is symmetrical or asymmetrical also has an effect. S. Negrini and A. Negrini investigated the postural effects of symmetric vs asymmetrical loads on the spines of school children. Forty-three school children with a mean age of 12.5 participated in this study. Children were evaluated by an optoelectronic device corresponding to their usual everyday school activities to determine that the average time spent getting to/from school was 7 minutes. The conditions included without an external load, 12 and 8 kg symmetrical loads, and an 8 kg asymmetrical load. Participants spent 7 minutes walking on a treadmill. Both types of loads changed posture with symmetric loads only affecting the sagittal plane, but asymmetric affecting all anatomical planes. There was a significant difference between the 8 and 12 kg with change in posture. It was concluded that the effect of backpack loads on schoolchildren needs to be evaluated more in the future to avoid back pain in the future (Negrini, S., & Negrini, A. 2007).

Single vs double strap backpack loading effects on gait and perceived exertion has also been investigated. Abaraogu et at., (2016), determined the influence of single strap and double strap on gait parameters and rate of perceived exertion on young adults. There were 25 participants, and each participant walked at a self-selected pace for six minutes under each of the three conditions. These conditions included no external load, backpack with 1 strap, and backpack with 2 straps. Gait parameters and perceived exertion were measured. The gait parameters that were measured included stride length, stride time, step length, step time, gait speed, and cadence. When analyzing gait with asymmetric and symmetric loads, gait wasn’t significantly different, but there was a higher perceived exertion when carrying the loads (Abaraogu et al., 2016).

As seen with literature, load carriage has an impact on biomechanical measures such as gait and balance. Load carriage also has an impact on the physiological aspects of an individual. Not only does the mass of the load have an effect, but also the positioning of the load. Some research has discovered that when comparing double strap bags and single strap bags, less energy is required and less muscles activated for double strap bags and bags placed in a high position. There is a gap in literature with how a golf bag affects balance. Studies that have investigated footwear in golfers concluded that footwear choice does not influence balance, but few studies have looked at the effects on balance of golf bag loads and how they are positioned on golfers.

Golf

Golf is a popular sport for all ages because there is less chance of injury and anyone can learn to play. Golf requires tactical and technical skill in order to be successful. According to Hardin and Zuegner (2003), golf became popular in America in the 1920s. Some factors that contributed to this popularity includes urbanization and increased leisure time. Another reason why golf became popular was magazines that talked about game enhancement, benefits, mythical nature of golf, and Bobby Jones (Hardin & Zuegner, 2003). The objective of the golf swing is to execute a swing that is consistent, accurate, controlled, and provides maximum distance throughout a round (Maddalozzo, 1987). To achieve this desired swing, one must have balance, flexibility, and strength to coordinate the complex set of movements (Sell, Tsai, Smoliga, Myers, & Lephart, 2007).

Golf is a seasonal industry because it relies on the weather and is in the leisure market. Currently, older generations make up a greater percentage of the market than younger generations. (Trolia, 2019). This means that the popularity of golf could decrease if the younger generation doesn't start to show an increase in interest. Trolia also noted that because golf can be an expensive sport to play, the economy has a huge effect on regular play (2019). In 2018, golf was behind fishing and camping for wholesale equipment dollars category in recreational sports (Alberstadt, 2018). This is because every golfer is dependent on equipment to play each round. The equipment category consists of clubs, balls, bags, and club components that only make up a portion of the 2.6 billions of dollars golf has on the market (Trolia, 2019).

Golf Mechanics

There are five parts in a full golf swing which includes address, backswing, downswing, impact, and follow-though. The address is the starting position and is made up of the ball position, stance, grip, and posture (Maddalozzo, 1987). When the feet are shoulder width apart during the stance, it allows full rotation of the hips which provides power from the lower body. This also increases stability (Maddalozzo, 1987). The backswing is initiated by rotation of the pelvis and upper torso. There is then a weight shift to the back foot allowing the hips to have full range of motion. The golfer must be able to control this weight shift and keep center of mass within the base of support so that they do not lose balance (Sell, Tsai, Smoliga, Myers, & Lephart, 2007). The downswing is the portion that is controlled by the lower body while the upper body rotates away from the target. It is important that the head of the club hits the ball with maximum velocity along the intended direction (Hume et al, 2005).

Lindsay, Mantrop, and Vandervoort analyzed the differences in swing between players of all skill levels. It was found that golfers with more success initiate the downswing from the lower body which creates a faster angular velocity. A faster angular velocity is also created when there is an earlier movement of the center of pressure to the front foot (2008).

Golfers with an earlier movement of center of pressure to the front foot as well as rate of change patterns in the mediolateral center of pressure, the downswing is more likely to generate a higher club velocity (Smith et al. 2017). This was found by using three-dimensional marker trajectories collected by using the Vicon motion analysis and force plates. Twenty-two low-handicap goflers participated in this study with their drives being analyzed (Smith et al. 2017).

Balance

Wells, Elmi, and Thomas conducted a study on the physiological correlates of golf performance in elite golfers. Participants included 15 men and 9 women that were all members of the Canadian National Golf Team. Anthropometrics such as standing and sitting height, mass, and limb length were measured. Flexibility was measured by the sit-and-reach protocol. Balance was then measured by having the athletes stand on one foot and place the other foot below the knee of the supporting leg. Athletes were then told to raise their heel of the supporting leg and hold it as long as possible with their hands on their hips. The trial ended when the heel touched the ground, or the hands moved from their hips. Abdominal muscles were tested by having the athletes hold a plank for as long as possible in a front position, dominant side, and nondominant side. Leg power was tested by having participants complete a vertical jump. Upper body strength was assessed using a pull-up protocol. The Leger multistage run test was used to measure cardiovascular performance. Finally, participant’s golf performance was assessed by calculating launch conditions of the golf ball at impact. These conditions included ball speed and carry distance. The balance test found that balance is important in executing shots from the fairway.

This is demonstrated in the weight shift that occurs from one leg to the other during the backswing portion. It was found that flexibility, balance, and core strength and stability are correlated with golf performance and should be included in training programs (Wells et al. 2009). This shows that balance is an important aspect in the golf swing.

One study investigated the relationship between balance ability and athletic performance. In some sports such as golf, soccer, and rile shooting, it has been found that elite athletes have better balance control compared to less skilled players especially when considering a unipedal static balance associated with weight shift during the golf swing. Balance in golf is important because players may have to swing with an uneven lie of the ball (Hyrsomallis, 2011).

Load Carriage in Golf

Load carriage, balance, and golf have been extensively studied individually, but there is a lack of research combining all of these elements. It has been found that increasing load carriage of backpacks and military packs increases metabolic demand, instability, and postural sway. Where the load is placed also has a big impact on muscle activation to maintain postural control and balance. This study will examine how load carriage in golf has an impact on balance. Specifically, this study will examine balance with no golf bag, single strap golf bag, double strap golf bag worn above the sacrum, double strap golf bag worn below the sacrum, and a golf bag on a pushcart.

A previous study conducted by Holland and Godwin (2020), identified the metabolic demands of carrying a single versus double strap golf bag. Participants included 16 male recreational golfers. The participants walked on a self-selected treadmill speed for 5 minutes for each of the three randomized trials under one of the three conditions. These conditions included no external load, a single strap bag, and a double-strap golf bag. The bags consisted of a standard set of clubs weighing 12.5 kg. Measurements taken included heart rate, respiratory minute volume, and oxygen consumption. The single-strap golf bag had significantly higher metabolic cost in heart rate, respiratory minute volume, and oxygen consumption than the double strap and unloaded conditions. This means that golf bags with a double strap may help reduce fatigue and risk of injury (Holland &Godwin, 2020).

A similar study was conducted by Ikeda that measured metabolic cost for single and double strap golf bags. Perceived comfort was also taken into account. Participants for this study included 15 healthy men between the ages 20-48. The study consisted of 2 walking trials on a treadmill while carrying either the single or double strap golf bag. Participants walked for 5 minutes while oxygen consumption, heart rate, perceived exertion, and perceived comfort were measured. The walking speed on the treadmill was 3 mph with a 2% grade. This study had the same results as Holland and Godwin (2020) that heart rate and oxygen consumption were significantly lower carrying the double strap bag. Comfort was also higher during the double-strap trial. This is because double strap bags represent symmetrical loads that increase stability and require less muscle activation (Ikeda et al, 2008).

Lastly, McDaniel, Merritt, and McLean (2020) compared the metabolic cost of pushing a golf bag and carrying a golf bag. Twenty-two participants (18 male and 3 female) carried a 25 golf bag for one mile in one trial and pushed the golf bag for a mile in another trial. They were instructed to keep a pace of 3.5 mph and were given feedback to adjust their speed every 1/16 mile. There was a 10 minute rest period between trials. VO2 and heart rate were measured. Pushing the golf bag using a pushcart had significantly less metabolic cost than carrying the bag (McDaniel, Merritt, & McLean, 2020).

CHAPTER III

METHODOLOGY

Participants

Participants were recruited in person by going to classes within the Health Sciences & Kinesiology Department with approval from the instructor. Participants included 3 males and females, college-aged (18-30) with no current metabolic, cardiovascular, or musculoskeletal disease. Possessing golfing experience within the past six months was necessary to participate. The total number of sessions required for each participate includes six total sessions with session one lasting approximately thirty minutes and the remaining five sessions lasting three hours. Each participate experiences five different testing conditions with one condition being tested each day. The five testing conditions include 1) no golf bag 2) single strap golf bag 3) double strap bag worn above the sacrum 4) double strap golf bag worn below the sacrum 5) golf bag on a pushcart.

Upon arrival at the Kinesiology Laboratory, participants were provided with a verbal and written description of the purpose, methods, and inclusion/exclusion criteria of the study.

Participants were asked to sign the informed consent once they agreed to the design of the study and fit the criteria. Participation in this study was completely voluntary.

Procedures

All data was collected at the Kinesiology Laboratory at Georgia Southern University. On the first day, all testing procedures and designs were explained to the participants and an informed consent and medical questionnaire was received. The participants were then familiarized with walking procedures and the static balance test. The following days 2-6 served as experimental days. During each testing condition, the participants were instructed to walk around a specific path in the lab with their load. At ever .5 mile, the participants removed their load and completed the balance test. This pattern continued until a total of three miles was walked. The balance test consisted of twelve total trials with each trial lasting twenty seconds in duration with a rest period of ten seconds in between each trial. Each condition was repeated three times including: eyes open standing on the BTrackS (San Diego, CA, USA), eyes closed standing on the force plate, eyes open standing on the AIREX Balance Pad (Power Systems Inc., Knoxville, TN, USA) positioned on the force plate, and eyes closed on the AIREX Balance Pad positioned on the force plate.

Data Analysis

Center of pressure (COP) was measured while the participant is quietly standing was analyzed using the force plates. The force plates quantify center pressure postural sway while somatosensory and visual environments are systematically altered. The dependent variables include the sway velocity components in the medial-lateral (M/L) and the anterior-posterior (A/P) directions and the root mean square of COP displacement in the A/P and M/L directions. Root mean square is a measurement of mean body sway so that conditions can be compared.

Sway velocity was measured to determine the change of the COP per second in the M/L and A/P directions. A higher value for sway velocity indicates decreased postural stability because of larger changes in position. Previous studies have recognized sway velocity as an appropriate measure in determining postural stability (Wade et al., 2004).

Statistical Analysis

For all dependent variables of interest 5x7 (Condition [control, single strap, dual strap above, dual strap below, push cart] x distance [Pre, 0.5m, 1m, 1.5m, 2m, 2.5m, 3m]) repeated measures ANOVA will be employed to determine a bag- or distance-main effect or bag x distance interaction. If an interaction is found, simple effects will be calculated to determine the nature of the interaction. If main effects are found, a post-hoc Bonferonni correction factor for multiple comparisons will be used to examine differences. All statistical analyses will be conducted using an *a-priori* alpha level of 0.05. Further, partial eta squared will be reported as measures of effect size.

CHAPTER IV

RESULTS

Results of the repeated measures ANOVA revealed a significant distance main effect for MLRMS in the eyes open firm condition ($F(6,12) = 3.04$, $p = 0.048$, $\eta^2 = 0.603$) and the eyes open foam pad condition ($F(6,12) = 5.26$, $p = 0.007$, $\eta^2 = 0.725$). These results suggest that MLRMS increases over the duration of the walk.

CHAPTER V

DISCUSSION

The results found that static balance decreased over the duration of the walk, regardless of load carriage style. These findings suggest that carrying loads for a long duration of three miles, may have an effect on golf performance because of the decrements of balance. This finding goes along with previous studies that analyzed the metabolic cost of carrying a single- versus double-strap golf bag (Ikeda, Cooper, Gulick, & Nguyen, 2008).

Findings of this study are also consistent with studies that investigated the metabolic cost of carrying different amounts of loads while walking on a treadmill. Holewijn (1990). found that heart rate and oxygen uptake increased regardless of load size. Hrysomallis (2011), conducted a study that showed why balance is important in golf. Elite golfers are more controlled when it comes to unipedal static balance that is seen in the golf swing (Hrysomallis, 2011). This is similar to results in this current study because of the balance needed on the uneven surfaces discussed in Hrysomallis's research (2011), with eyes open on the foam pad being significantly different than eyes open on the stable plate. As mentioned previously, balance is an important part of golf and should be included in training programs to see best results (Wells et al., 2009).

The effects of backpacks on school children have been extensively studied. One study found that asymmetric loading had effects on balance in all anatomical planes whereas symmetric loads only had an effect on the sagittal plane. (Negrini & Negrini, 2007). This differs from the findings of this study because balance was affected throughout the six miles, regardless of placement.

Lastly, this study differed from findings from McDaniel, Merritt, & McLean that compared metabolic cost of using a pushcart and carrying a golf bag (2020). They found that using the pushcart had significantly less metabolic cost than carrying the golf bag. Results differ from this current study because balance was affected in both conditions.

CONCLUSIONS

The results of the present study suggest that standing balance may be affected by extended durations of walking while carrying a golf bag. However, current evidence further suggests that the type of carrying style does not make a significant difference on balance measures. Golfers and coaches can utilize these results and be aware of potential balance decrements and concurrent performance decrements, especially in the latter stages of a round.

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