Investigation of Hand Forces Produced While Playing Golf: With the Use of New Weareble Sensor Technology to Assist in the Hand Function of Patients with and without Hand Arthritis

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1 OBJECTIVES

Arthritis is the most prevalent chronic health condition without a cure, affecting 1 in 5 adults in Canada (The Truth About Arthritis, 2018). This chronic condition makes playing sports, such as golf, very difficult for those affected. Arthritis causes pain, stiffness, and results in permanent damage and deformation in the joints leading to decreased mobility (The Truth About Arthritis, 2018).

With 61% of people who play golf being over the age of 50 (Golf Player Demographic Statistics, 2016) and with arthritis being more common in older adults, there is a large population of individuals who have arthritis and play golf. Comprehensive examinations have not been done on current golf grips to analyse the forces at the hand and golf club grip interface. Currently there are a few commercially available arthritis specific golf grips, however they are not based on empirical measurements nor have they been properly tested to determine their effectiveness at reducing joint pain in a player's hands. The grip of a golf club is the only contact point between the player and the club, making the player's grip force and the golf grip important elements of the game. However, grips are the most overlooked piece of equipment in a golfer's bag (Golf Grips Buying Guide, 2017).

Grip forces in golf have been previously studied, but have been limited to a small number of participants and have focused exclusively on the driver (Komi, Roberts, & Rothberg, 2008). One such study fabricated a steel-shaft of a driver with strain gauges placed on the handle beneath the grip at various locations (Budney, 1979). Since the strain gauges were attached to the grip, the fingers whose forces were being measured would change based on finger orientation on the grip. With a sample size of one, the lack of clarity in which fingers were exerting which forces, and the lack of grip force quantification (strain gauges were not calibrated) were major limitations on this study, thus limiting the knowledge gained (Budney, 1979).

Another study evaluated grip force signatures during a standard golf tee shot, utilizing 31 Flexiforce 0.1mm thin-film, single load cell type sensors strategically placed on two gloves in 20 right-handed, male golfers with handicaps ranging from zero to no handicap (Komi et al., 2008). The large sample size increased the validity of the study; however, players had to wear a glove on each hand, which could have changed their natural grip pattern due to the added bulk of the gloves. While a few other studies have evaluated various aspects of the game, there is very little female representation, with none having evaluated hand forces in female players. Thus, there is a gap in golfing related research as the number of female golfers grows.

Sports and technology have been studied and developed for many years, therefore increasing the popularity of sports biomechanics in recent years. With advancements in wearable technology, such as a reduction in component size and the addition of Bluetooth capabilities, the evaluation and development of new training techniques and equipment have become more sophisticated. These advancements elevate and enhance players' performance through the design of safer equipment which decreases injuries without limiting players' mobility. Golf grips have evolved from leather wraps to manufactured rubber grips (Golf Grips Buying Guide, 2017). Although they have evolved, golf grips

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remain the most overlooked piece of golfing equipment.

Therefore, the objective of this study is to systematically analyse the hand forces produced from various golf grips at the distal-phalanges of the hand-grip interface using a mid-iron club in individuals with and without hand arthritis using new wearable sensor technology.

2 METHODS

2.1 Wearable Sensor Technology

The forces that occur at the hand-grip interface in a golfer's grip were measured with a new sensor system developed by Pressure Profile Systems Inc., called the Finger Tactile Pressure Sensors (FingerTPS). This technology provides an alternative technique of measuring forces at the hand-grip interface and is the most accurate on today's market, with 100x better minimum pressure detection and 50% better pressure sensing resolution compared to typical resistive tactile sensing technology (Capacitive Tactile Pressure Sensors, 2018). The capacitive sensors are enclosed in a conformable, micro spandex finger cot, which comfortably slides over the players' fingers (Capacitive Tactile Pressure Sensors, 2018). The finger cots are minimally invasive and come in multiple sizes to accommodate for different finger sizes and shapes (Capacitive Tactile Pressure Sensors, 2018). The data is wirelessly transmitted via Bluetooth, which allows players to freely swing the golf club without risk of entanglement in cords.

2.2 Test Protocol

Hand measurements of each participants' bottom gripping hand were taken without the sensors on: the length of their hand from the base of the palm to the tip of the middle finger, the length of their middle finger, and the breadth of their hand. One sensor was placed on each participant's index, middle and ring finger of their bottom gripping hand (right hand for a right handed player and left hand for a left handed player). Latex finger cots were placed underneath and overtop of the sensors in order to protect the sensors from the high shear force experienced at the hand-grip interface during a golf swing. Each sensor has a single wire that is connected to a receiver, which securely and comfortably attaches to the participants wrist via a Velcro strap. The receiver connects to a small wireless transceiver that is lightweight and attaches to a belt that is worn around that participant's waist. An athletic compression sleeve ensures that the single, long wire connecting the receiver to the wireless transceiver is not obstructing the player's swing. Each sensor is calibrated with a single degree of freedom load cell designed by Pressure Profile Systems Inc., specifically for the FingerTPS sensor system, which minimizes recalibrations thus saving time and improving results (Capacitive Tactile Pressure Sensors, 2018).

The participants did not wear a golf glove on either hand for the test and hit off of artificial turf into a net. They were each evaluated on their maximum golf grip strength by gripping a standard size, medium firmness grip in their normal golfers gripping style (as they would if they were to swing the club) and asked to grip the club as tightly as they could. The participants performed two golf shots with each of the 12 seven iron clubs that consist of several types of standard and arthritis golf grips, varying in material and diameter size.

2.3 Participants

The inclusion/exclusion criteria for patient recruitment is that they were 18 years of age or older and play or go to a golf range a minimum of two times a year, allowing for different skill level golfers to be tested while excluding individuals who have never played golf. The data presented here has a sample size of 4, two right handed female golfers aged 18-35 and two left handed male golfers aged 36-50. Participant 1 was an experienced golfer with a handicap of 3.4, participant 2 was a recreational golfer with a handicap of 20, and participants 3 and 4 were professional players with handicaps below 1.

2.4 Testing Equipment

The various types of Golf Pride and Arthritis grips that were tested in this study cover the spectrum of grips that are designed in order to gain a better understanding of each grip and the different forces produced. The CP2 Pro soft performance grips in standard, undersized, mid-sized and jumbo diameters are built for comfort and control featuring a larger lower hand diameter and high-tack rubber. The soft rubber allows for lighter grip pressures and dampens the vibration through impact (Frequently Asked Questions , 2017). The MCC Plus4 medium firmness hybrid grips in standard, undersized and mid-sized diameters contain two materials to create the best combination of moisture management and feel, featuring cord in the top hand and soft rubber in the bottom gripping hand (Frequently Asked Questions , 2017). The Z-Grip hard firmness grips in a standard and mid-sized diameter are corded, such that they contain a cord material in the composition of the grip to allow for better traction with the drawback of the grip being more abrasive and uncomfortable (Golf Grips Buying Guide, 2017). There are also three different grips specifically designed for arthritis that were being tested. The Winn oversized soft firmness grip is a wrapped grip which creates a soft surface texture that provides a tacky touch (Golf Grips Buying Guide, 2017). The Lamkin arthritis grip and Tacki-Mac arthritis standard grip are designed based on the unique serrated or 'nubbed' texture, increasing tactile feedback and prompting a lighter grip pressure as well as vibration dampening (Artritis Golf Grips, 2017).

2.5 Data Analysis

The data was exported from the Pressure Profile Systems software after testing and graphs were created using Matlab 2017b from The MathWorks Inc., USA. Each graph demonstrated the variation in force for each of the different grips in the index, middle, and ring fingers of the bottom gripping hand through the golf swing. The graphs showed force in Newtons on the y-axis and time in seconds on the x-axis.

3 RESULTS

Preliminary data from four healthy participants' bottom gripping hand was collected. The hand measurements of each participant were taken before testing began and are shown below in Table 1.

Table 1: Hand measurements for participants 1 to 4 in centimetres. Hand length was from the base of the palm to the tip of the middle finger, middle finger length was from the base of the metacarpophalangeal joint to the tip of the middle finger, and hand breadth was taken at the widest point of the palm.

Participants	Hand Length [cm]	Middle Finger Length [cm]	Hand Breadth [cm]
1	17.9	8.0	8.7
2	16.4	7.0	7.5
3	19.0	8.5	9.3
4	20.0	8.4	10.0

Golf grip strength was measured for each player; participants 1 and 4 had a higher overall maximum golf grip strength and participant 2 had the lowest. In evaluating the peak forces that occurred throughout each grip, participants 1 and 2 demonstrated a larger force output across all the fingers in the larger, softer firmness grips and a lower force output in the smaller, harder firmness grip. Alternatively, in participants 3 and 4, the smaller, softer firmness grips produced the higher forces and the larger, softer firmness grips produced lower force outputs. As participants 1 and 2 had smaller hand measurements than participants 3 and 4, this demonstrates that hand size may be linked to different force outputs in different types of grips. A comparison chart showing hand size to the force output of the grip that produced the highest and lowest forces in each participant is demonstrated in Figure 1.

The individual graphs shown in Figures 2-5 exhibit the high and low force outputs for participants 2 and 3. These graphs also demonstrate the repeatability of the force pattern during each participants swing and how they differ between participants 2 and 3. Out of the three arthritis grips tested, the serrated grips (Lamkin arthritis grip and the Tacki-Mac arthritis standard grip) had the highest force output for all the participants across all the fingers tested (Figure 6). There is also a potential link seen between the high force outputs in the non-arthritic grip compared to the serrated arthritis grip of the participants as they have very similar results (shown in Figures 5 and 6).

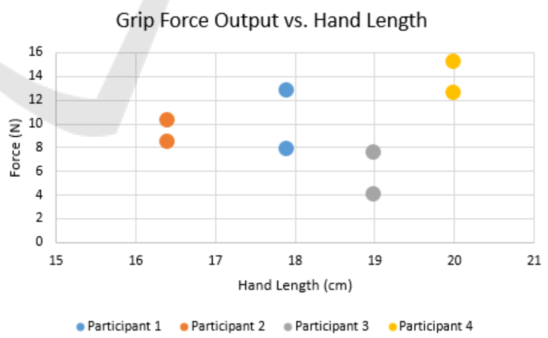

Figure 1: Hand size to force output of the golf grip that produced the highest and lowest forces.

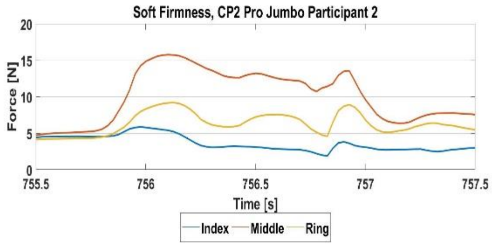

Figure 2: The grip that produced the highest force output for participant 2 was with the CP2 Pro, soft firmness, jumbo grip.

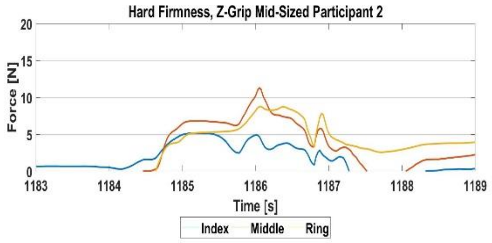

Figure 3: The grip that produced the lowest forces output for participant 2 was with the Z-Grip, hard firmness, mid-sized grip.

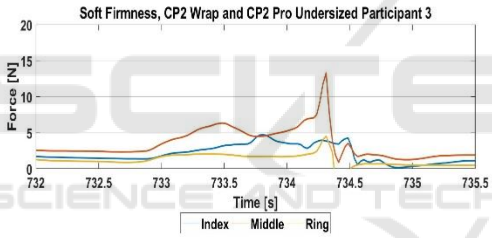

Figure 4: The grip that produced the highest forces output for participant 3 was with the CP2 Pro, soft firmness, undersized grip.

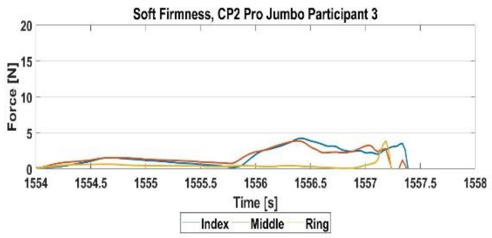

Figure 5: The grip that produced the lowest forces output for participant 3 was with the CP2 Pro, soft firmness, jumbo grip.

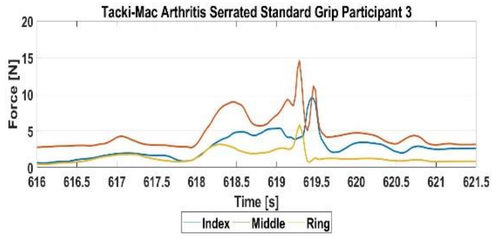

Figure 6: The Tacki-Mac arthritis standard grip demonstrated by participant 3.

4 DISCUSSION

The preliminary results are demonstrated by the first four healthy participants of this study. The data showed force variations throughout the swing and that each player had repeatable force output patterns across all the various types of grips, with variations in force magnitude being evident between each participant. Preliminary data also indicates that there might be a relationship between grip materials and geometry to finger force as well as hand size to finger force. Currently, active recruitment of patients with and without arthritis is ongoing to compare the results of healthy players to those with arthritis.

Previous studies (Budney, 1979; (Komi et al., 2008) have demonstrated that each golfer has a repeatable grip force pattern with the magnitude of force varying between golfers, which was also demonstrated from the results of this current study. Unlike the High Speed Video study (Komi et al., 2008), which utilized 31 sensors on both hands, this current study provides a more targeted measurement as the bottom gripping hand holds the grip more so in the fingers unlike the top hand that holds the grip in both the palm and the finger segments. Also, as osteoarthritis primarily affects the DIP and PIP joints of the hand, the measurement of the distal finger segments will provide the most accurate and relevant measurements to the research question of this project. The limitations of this study are that only the index, middle, and ring fingers of the bottom gripping hand are being measured.

The preliminary data collected in this study potentially demonstrates a correlation between hand size and grip type. Comparing the various graphs as to which grip produced larger and smaller forces for each participant, there is a potential link between hand size and grip (material and diameter size) as to which grip produces a larger force output. For participants 1 and 2 who had smaller hand sizes, the material of the grip was the biggest influence in if a high or low grip force was produced. For participants

3 and 4 with larger hand sizes, the diameter size of the grip was the most influential component.

The majority of golf grips are made of a foam or rubber material, as it is easy to shape, produce and can offer different firmnesses while maintaining an adhesive feel (Golf Grips Buying Guide, 2017). Many manufacturers have begun to experiment with different rubber hybrids by including silicon, elastomers and plastics into the grips to give them different properties for different climates and preferences (Golf Grips Buying Guide, 2017). There are generally three levels of firmness with the softest firmness being best for climates that are dry with little rain, the hard firmness grips are best for hot and humid or rainier climates and the medium firmness grip are the standard, versatile grip.

The other component of golf grips is the size (diameter) of the grip. Studies suggest that up to 75% of players are using the wrong size grip with there being five different diameter size grips: standard, junior, undersized, mid-sized, and oversized/jumbo (Golf Grips Buying Guide, 2017). The diameter of the grip can also influence the shot shape (draw or fade; curve to the right or curve to the left for a right handed player) as a larger grip limits wrist movement and smaller diameter grips allow for more manipulation (Golf Grips Buying Guide, 2017). Many players also add athletic tape underneath their grip to make minor adjustments to their grip size allowing them to customize their grip to their game.

Looking specifically at the arthritis grips, the serrated arthritis grips (Lamkin arthritis grip and the Tacki-Mac arthritis standard grip) seemed to produce the highest force outputs out of the three grips tested. The graphs of the serrated arthritis grips compared to the grips that produced the highest force output in the non-arthritis grips showed similar magnitudes of force across all the participants. This potentially demonstrates that this arthritis-assisted golf grip design may not be the best solution for reducing the forces in a player's hands. As well, all four players commented that the serrated grips were the most uncomfortable to hold and that they would not purchase these grips for their own clubs. This suggests that currently marketed arthritis grips may not be the best option for comfort and in reducing harmful high forces when swinging a golf club. However, further tests need to be conducted on different skill level golfers, as well as on individuals with and without hand arthritis, to obtain an accurate representation of the forces that occur in a players hands and to show if there is a consistent pattern between the various types of grips (both size and material).

With arthritis being the most prevalent chronic health condition with no cure (The Truth About Arthritis, 2018), and with the advances in technology specifically in wearable devices, the understanding of the effects that various materials and diameter sizes of golf grips have on the forces occurring at the hand-grip interface can be evaluated. This research will contribute to the understanding of the complex structure of the hand and can be translated to other sports such as tennis, squash, baseball, etc. By providing a better understanding of the mechanics of arthritis and its relation to sports, the design of more advanced sporting equipment can be developed to protect players' joints and be more customizable to each players' performance.

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