Comparison of Perceived Golf Shot Performance, Upper Limb Stress and Ball Flight Characteristics between Solid and Brush Fiber Hitting Mats.

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ABSTRACT

The purpose of this study was to evaluate two different types of golf mats typically used at practice facilities. One was a solid mat comprised of dense foam while the other consisted of a brush like surface made of long flexible nylon strands packed closely together and set in a vertical orientation. The investigators were interested in whether subjects perceived any difference in the comfort or quality of shots made from the different surfaces. Furthermore, the ball flight characteristics of initial launch angle and ball spin rates were also compared between the two hitting mats. Twenty male and 3 female amateur golfers, with handicaps ranging from 4 to 28, participated in the study. Ball flight characteristics were evaluated using the Motion Analysis Technology by Taylor Made (MAT-T) system. A questionnaire was used by the subjects to rate which mat they thought best reduced the impact forces at ball strike as well as allowed them to achieve the best quality of ball contact. Results showed that a large majority of participants felt the brush mat created less impact force and allowed for better quality of ball contact when compared with the solid mat. They also felt it better simulated a grass fairway than the solid mat. Overall, 81% of participants preferred hitting off the brush fiber mat rather than the solid mat. Analyses of the data retrieved by the MAT-T system revealed that despite the softer, more realistic feel of the brush fiber mat, there was no significant effect on ball launch characteristics between mats.

Key Words: Overuse Injury, Driving Range, Motion Analysis

INTRODUCTION

Golf is an increasingly popular sport with over 55 million participants world-wide (Farally et al. 2003). The popularity of golf is likely due to a number of factors, including health and social

reasons, although many players enjoy the challenges that golf provides and as such seek ways to improve their performance.

The golf swing is regarded as one of the most difficult biomechanical motions in sport to execute (Nesbit & Serrano 2005). As a result, the complex and powerful movement associated with the golf swing requires repetitive play and practice in order to improve. It is not unusual for elite professional golfers to repeat these powerful movements 300 times or more per practice session (Thériault et al., 1998).

The repetitious and ballistic nature of the golf swing results in considerable risk of injury particularly amongst lower skilled recreational golfers who have less efficient swing styles. In terms of location, approximately 50% of all golf injuries affect the upper limb (shoulder, elbow, wrist and hand). This compares with 30% for injuries to the spine and approximately 15% for lower limb injuries. (McCarroll et al. 1990, Batt 1992, McNicholas et al. 1999, Gosheger et al., 2003).

The majority of upper extremity injuries from golf are due to overuse (Gosheger et al. 2003, Wiesler 2005). One aspect that may contribute to overuse injuries is the surface (i.e. turf) on which the ball rests when it is struck by the golf club. Golfers often spend hours at a practice facility hitting off artificial turf, a surface necessitated by such factors as; space limitations, maintenance costs, local climate, or indoor facility. Players typically contact the turf before, during or after ball impact, thereby creating high resistance loading on the upper limbs. Repetitive & excessive loading may contribute to injuries such as wrist tendonopathy, elbow epicondylitis or rotator cuff strain (Kim et al. 2004, McHardy et al. 2006).

While a number of manufacturers produce simulated turf mats, there are typically two different types installed at practice facilities. One type is a solid mat that typically has a thin layer of a durable synthetic turf that is implanted onto a 30mm thick base comprised of dense foam (Figure 1a). The other common mat consists of a pliable brush-like surface comprised of closely packed vertical strands of nylon fibers (approximately 40mm long) set into a hard polymer base (Figure 1b). The flexible nature of the vertical fibers should reduce the amount of resistance loading felt in the upper limbs during contact between the golf club and the hitting surface. However, to date no previous study has investigated impact forces using different types of practice mats. Furthermore, it is not known whether ball flight characteristics vary between the different mats.

The purpose of this study was to compare the perceived impact forces, upper limb stress, quality of shots and similarity to hitting from grass between two common types of hitting mats. In additional to the perceived results, post-impact ball flight data, specifically launch angle and spin rates, were also compared.

Figure 1a Solid mat

Figure 1b Brush fiber mat

METHOD

Participants

Subjects in this study consisted of 20 male and 3 female amateur golfers with handicaps ranging from 4 to 28. A wide range of skill level players were used to best mirror the varied abilities of golfers who typically use these types of hitting mats. The average subject in our study had a handicap of 16.1, visited a driving range approximately once per week in the off-season, but twice a week during the golf season and typically hit one large bucket of balls per session (large bucket is usually between 60-90 balls). Each subject gave informed, written consent to participate in accordance with the University of Calgary's Conjoint Health Research Ethics Board policy on research using human subjects.

Experimental Conditions

All testing was performed indoors using a 6-iron to hit a standard golf ball into a net. A 6-iron was chosen because it would be normal to use a club such as this when hitting off mats at a practice facility. The Motion Analysis Technology by TaylorMade (MAT-T) launch monitor system (TaylorMade-adidas Golf Company, Carlsbad, California) was used to calculate the initial ball launch angle and backspin of each shot.

Each participant completed two trials of 10 swings on each mat. The hitting mat used for the first 10 shots was randomly assigned. The hitting mat was changed after each series of 10 shots. This was done so subjects could better compare the perceived performance on each mat. A total of 20 swings per subject were completed on each mat. The brush fiber and the solid hitting mats were both provided by Fiberbuilt® Manufacturing Inc (Calgary, Alberta).

Subjects were asked to complete a questionnaire after completing the second series of 10 swing trials on each mat. Two sets of questionnaire data were thus collected, one for each hitting mat. The questionnaire was used to help determine the perceived magnitude of the contact forces between the golf club and hitting mat, the perceived stress that this contact produced on the upper limbs, the quality of the club–to-ball contact, and how each mat compared to hitting off a natural grass surface.

A final questionnaire was conducted at the end of all the trials and after the initial questionnaire was completed and handed back to the research team. It served as the definitive indicator of which mat each subject preferred as only two choices of answers (brush or solid mat) were provided for each question. Additional space was provided for subjects to comment why they preferred one mat over the other. The study questionnaires were piloted and refined to ensure participants' understanding of the questions matched those of the investigators.

Data Analysis

Before any data retrieved from the MAT-T system launch monitor was analyzed, a function was designed to eliminate any data that was outside the realm of a normally executed shot. To discard this non-viable data, the mean and standard deviations of the launch angles and spin rates of all the shots of all the players were determined. Any data that was outside 2.5 standard deviations above or below the launch angle mean was discarded. Any data outside 1.5 standard deviations above or below the spin rate mean was discarded. Close to 15% of the total shots were discarded with an approximately equal proportion of shots coming from each mat. Student t-tests were used to compare the launch angle and spin rate data between the two mats.

The initial questionnaire completed after the second trial on each mat, consisted of a 0 to 10 rating system that required subjects to circle the number that best matched their perceptions within the categories identified above. Student t-tests were used to compare the questionnaire results between the two mats.

RESULTS

MAT-T System Launch Monitor Data

Launch angle refers to the angle relative to horizontal the golf ball travels immediately after leaving the club face (i.e. immediately after impact). The average launch angle on the brush fiber mat was 18.92 $\pm$ 2.10 degrees. The average launch on the solid mat was slightly lower at 18.63 $\pm$ 1.80 degrees. These findings were not statistically significant (p value = 0.33).

Spin rate refers to the amount of backspin imparted to the golf ball from impact with the golf club and measured immediately after the ball leaves the club face. The average spin rate of shots hit from the brush fiber mat was 4483.7 $\pm$ 1069.7 rpm, compared to 4436.4 $\pm$ 1084.4 rpm for shots hit from the solid mat. These findings were not statistically significant (p = 0.65).

Initial Questionnaire Data

The results from the initial questionnaire, completed after the second trial of 10 shots for each hitting surface, are presented below.

Absorption

The term absorption was used to represent impact loading between the golf club and the hitting surface. A rating of 10 represented the highest possible absorption ability (i.e. least impact

loading) and was defined as the equivalent of hitting off a tee without striking the ground while the lowest absorption was the equivalent of hitting off a hard unyielding surface like a piece of wood. The brush fiber mat received an average absorption rating of 7.6 out of 10. The solid mat received an average rating of 4.3. The statistical strength of the difference of these means was very strong (p=0.00001). Overall, 82% of the subjects gave the brush fiber mat a better absorption rating, while 9% gave the solid mat a superior rating. The remaining 9% felt that both mats were equal in their absorption ability.

Comfort

Comfort was a reflection of the amount of stress produced in the upper limbs during impact with the hitting surface. A rating of 10 represented the highest comfort, i.e. the least amount of upper limb stress, while 0 represented grimacing pain. The brush fiber mat received an average comfort rating of 7.9 out of 10. The solid mat received an average rating of 5.7. The statistical strength of the difference between these means was strong (p=0.0005). Overall, 74% of the participants gave the brush fiber mat a higher comfort rating, while 9% gave a higher rating to the solid mat. The remaining 17% rated both mats equally.

Quality of shot

This variable reflected subjects' perception of the quality of ball contact achieved on each mat. A rating of 10 represented the best possible quality of ball contact that the subject felt would have resulted in maximum distance and accuracy. The brush fiber mat received an average rating of 7.3 out of 10 while the solid mat received an average rating of 6.7. The statistical strength of the difference between these means was strong (p=0.005). Overall, 61% of the subjects gave the brush fiber mat a superior rating in this category while 17% gave the solid regular a higher rating. The remaining 22% of the subjects felt the quality of ball contact was equal for both mats.

Grass Simulation

The final question compared subjects' perception of how well each mat simulated hitting off a natural grass surface. A rating of 10 represented the best simulation, i.e. the mat felt exactly the same as hitting from a lush fairway. The brush fiber mat received an average rating of 7.1 out of 10 compared to 5.0 for the solid mat (p=0.001). Overall, 61% of the subjects gave the brush fiber mat a higher rating than the solid mat. This compared with 13% who gave the solid mat a higher rating. The remaining 26% of participants gave both mats an equal rating.

Final Questionnaire Data

Table 1 summarizes the results from the questionnaire administered after all testing was completed. As evidenced from the results, the brush fiber mat was preferred by a minimum of 80% of the study participants for each of the categories surveyed. An additional question was included in this final questionnaire which asked which mat the participants preferred. Overall, 81% of subjects preferred hitting off the brush fiber mat over the solid mat.

Table 1 Results of Final Questionnaire

Question	Subject Preference (%)	
	Brush Fiber Mat	Solid Mat
1. Which mat best absorbed the impact of your club hitting the ground?	85.7	14.3
2. Which mat resulted in the least upper limb stress during ball contact?	90.5	9.5
2. Which mat permitted the best quality of ball contact?	80.0	20.0
4. Which mat best simulated hitting off a lush fairway?	81.0	19.0
5. Which mat do you prefer hitting off?	81.0	19.0

DISCUSSION

Results from the questionnaire portion of this study showed that perceptual differences clearly exist in how different types of practice mats affect upper limb stress and the quality of golf shots. These authors are unaware of any other study that has examined the influence of the hitting surface on similar health and performance characteristics.

Much of the stress associated with hitting a golf shot occurs at impact when club head speed is at maximum velocity (McHardy et al. 2006, McHardy et al. 2007). McHardy and Pollard (2005) reported an association between increased impact loads and increased risk of wrist injury. It stands to reason that upper limb impact loading will be influenced by the surface the golf ball is resting upon prior to impact. Golfers in this study clearly indicated the perception that hitting balls from the brush fiber mat resulted in less impact force and produced less discomfort on their upper limbs than the solid hitting mat. Therefore it would seem reasonable to suggest that it would be less likely for a golfer to be injured when hitting balls off the brush fiber mat compared to a solid practice mat.

The reason the brush fiber mat appears to be more comfortable to hit from likely relates to the fact that when stacked together, the vertical fibers are strong enough to hold up a golf ball, yet flexible enough to allow the golf club to pass through without a lot of resistance. A normal golf shot with an iron off a fairway typically involves taking a divot. A divot is the removal of a small piece of grass immediately in front of the ball caused by the club head moving below the bottom of the golf ball just after impact. Since a golfer is used to taking a divot when playing, hitting a similar shot off a solid mat at a practice facility would result in greater impact loading and hence upper limb stress than a non-solid mat. Furthermore, a miss-hit shot such as hitting

"fat" where a larger than usual divot is taken would result in even greater upper limb stress. In order for the golfer to reduce the impact stress when practicing they would need to alter the nature of the shot (i.e. take less of a "divot"), decrease the intensity of the swing, decrease the number of balls struck, or a combination of all three factors. All of these adjustments would negatively impact the ultimate goal of practicing – improving the magnitude and consistency of performance on a golf course.

Reducing impact forces and minimizing upper limb stress are desirable elements when practicing golf shots provided this also doesn't negatively influence the goal of practicing. The results from this study showed the majority of subjects felt the quality of shots hit from the brush fiber mat was better than from the solid mat. Furthermore, a significantly greater number of subjects felt that hitting balls from the brush fiber mat more closely resembled hitting balls off natural grass. These results would again suggest that practicing from a brush fiber mat would not adversely affect the goal of practicing to the same extent as the solid mat. In addition to these observations on subjects' personal preferences, our quantitative motion analysis data from the MAT-T system clearly showed no differential effect of the two types of surfaces on launch conditions, which in turn reflects the similarities with regard to the nature of the ball strike with the 6-iron.

The results from Table 1 most strongly reflect subjects' overall preference for the brush fiber mat as subjects could only select one type of mat for each of the 5 questions. Results showed that a minimum of 80% of the study participants selected the brush fiber mat over the solid mat in each of the categories. The largest perceived difference between mats pertained to upper limb stress, with almost 91% of subjects stating they felt the brush fiber mat produced the least stress during impact. When subjects were specifically asked which mat they preferred to hit balls from, 81 % selected the brush fiber mat. Subjects that commented on why they preferred the brush fiber mat typically stated; "better simulated a real golfing experience," "allowed for better ball contact," and "felt like I could miss-hit without discomfort." Participants who preferred the solid mat stated that this mat was "smoother and lighter to hit off," and "(its) firmness made it easier to hit off."

While the results of this study provide valuable information for golfers, golf coaches, healthcare providers and likely practice facility proprietors, several limitations exist in the interpretation of these finding. It would have been useful to include a natural grass surface in this study. However the testing was performed in an indoor laboratory setting and thus made the use of natural grass impractical. Since all of the study participants played golf regularly, it was felt that subjects would be able to make valid comparisons of their hitting experiences on the artificial mats with a natural grass surface.

As mentioned above, testing was performed inside a laboratory setting where subjects hit golf balls into a large net. It is not known whether the results would have differed had subjects hit balls at an actual large open practice facility. It is possible subjects may have been able to more accurately judge shot quality had they been able to see the outcome (i.e. ball flight) of each shot.

Future research should address the limitations addressed above. In addition, comparison of upper limb stress and impact absorption between different hitting surfaces would be enhanced

by measuring these factors more quantitatively (e.g. using strain gauges, vibration sensors, forearm electromyography).

APPLICATION

It would be reasonable to suggest that virtually all golfers would prefer to hit practice shots from a natural grass surface. However, since many practice facilities do not have a natural grass hitting area, results from this study provide valuable insight into how different artificial surfaces compare in terms of comfort and quality of golf shots. Knowing that a brush like hitting surface may allow a higher quality of ball contact and more closely simulates natural grass should help golf instructors when providing lessons to golfers seeking to improve their performance. Furthermore, the reasonable possibility the brush fiber mat reduces impact forces and decreases stress on the upper body should help health care practitioners make more informed recommendations to their golf patients when discussing return to activity guidelines.

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REFERENCES

Batt ME. (1992). A survey of golf injuries in amateur golfers. *British Journal of Sports Medicine*, 26(1): 63-65.

Farrally MR, Cochran AJ, Crews DJ, Hurdzan M J, Price RJ, Snow JT, Thomas PR. (2003). Golf science research at the beginning of the twenty-first century. *Journal of Sports Sciences*, 21(9); 753–765.

Gosheger G, Liem D, Ludwig K, Greshake O, Winkelmann W. (2003). Injuries and overuse syndromes in golf. *American Journal of Sports Medicine*, 31(3): 438-443.

Kim DH, Millett PJ, Warner JJP, Jobe FW. (2004). Shoulder Injuries in Golf. *American Journal of Sports Medicine*, 32(5): 1324-1330.

McCarroll JR, Rettig AC, Shelbourne KD (1990). Injuries in the amateur golfer. *Physician and Sportsmedicine*, 18: 122-126.

McHardy, A, Pollard HP. (2005). Golf and upper limb injuries: a summary and review of the literature. *Chiropractic and Osteopathy*, 13:7.

McHardy, A, Pollard H, Luo K. (2006), Golf injuries: a review of the literature. *Sports Medicine*. 36(2): 171-187.

McHardy A, Pollard H, Luo K. (2007), One-year follow-up study on golf injuries in Australian amateur golfers. *American Journal of Sports Medicine*, 35(8): 1354-1360.

McNicholas MJ, Neilsen A, Knill-Jones RP. (1999), Golf injuries in Scotland. In: *Science and Golf III: Proceedings of the World Scientific Congress of Golf.* Farrally MR, Cochran AJ (Eds). Champaign, Illinois: Human Kinetics, 65-72.

Nesbit SM, Serrano M, (2005), Work and power analysis of the golf swing. *Journal of Sports Science and Medicine*, 4: 520-533.

Thériault G, Lachance P. (1998), Golf injuries: an overview. *Sports Medicine*, 26(1): 43-57.

Wiesler, E.R., Lumsden, B. (2005). Golf injuries of the upper extremity. *Journal of Surgical Orthopaedic Advances*, 14(1): 1-7