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The Effects of Surface Composition on 6-weeks of Plyometric Training

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ABSTRACT

Background: Plyometric training programs may be performed on a hard surface or a soft surface to target specific training adaptations and enhance jump performance. However, it is unknown how surface compliance impacts jump performance. **Objective:** To compare changes in horizontal lower body power following a 6-week plyometric training program performed on a soft surface (n = 9) and a hard surface (n = 11). **Methods:** This was a quasi-experimental study. University students (N = 20; males = 11, females = 9; age: 20.4 ± 3.7 yr; body mass: 68.4 ± 12.5 kg; height 1.7 ± 0.1 m) with a history of being physically active volunteered to participate. Participants performed an initial pre-test standing long jump (SLJ), measured in centimeters (cm), then went through an accommodation period to be familiarized with training demands. A post-accommodation pre-test for SLJ was then completed. After the accommodation period, a 6-week plyometric training program was conducted. Following the completion of the training, a post-test was performed. The SLJ distance was analyzed with a 2 (surface) x 2 (time) repeated measures ANOVA. **Results:** There was no interaction for surface, but there was a main effect for time. Both training groups improved jump distance from pre- (soft surface = 191.6 ± 34.6 cm, hard surface = 216.1 ± 25.4 cm) to post-test (soft surface = 205.7 ± 38.8 cm, hard surface = 227.2 ± 23.4 cm). **Conclusion:** Practitioners designing plyometric training programs to increase lower body horizontal power may perform the training sessions on a soft surface or a hard surface and see similar improvements in horizontal jump performance.

Key words: Plyometric Exercise, Fatigue, Muscle Fatigue, Wood, Wrestling, Young Adult

INTRODUCTION

Horizontal lower body force production is the ability to produce force into the ground in the forward direction (Wakai & Linthorne, 2005). The ability to generate power in the horizontal plane is an important component in athletics, such as track and football, which require explosive leg and hip power for sprinting and jumping (Nagaraja et al., 2017). A common training modality to increase horizontal power generation is plyometrics (Ramirez-Campillo et al., 2020). One common environmental variable that can be altered during plyometric training is the surface composition. Training on different surfaces has been related to improving training adaptions in the stretch shorting cycle. The surface composition may play a role with training adaptions, previously it has been suggested that soft surface training may lead to improvements on the musculoskeletal system, while training on hard surface may lead to improvement in mechanical efficiency that is associated with neuromuscular improvement (Ramirez-Campillo et al. 2013).

While plyometric training is typically performed on a hard-ridged surface, like a gymnasium floor, plyometric training can also be performed on softer surfaces such as grass, mats, and in water. Plyometric exercises on a soft 5 cm wrestling mat have been shown to generate similar horizontal power and peak ground reaction forces and result in similar increases in both vertical and horizontal displacement as compared to a wood gymnasium floor (Jenses et al., 2010). Additional benefits of performing plyometric training on a soft surface have also been documented. For example, Ramirez-Campillo et al. (2013) indicated plyometric training on sand resulted in a decrease in muscular fatigue. While Katkat et al. (2009) and Elvan et al. (2019), indicated training on a non-ridged surface minimized muscle damage and repetitive use injuries. More recently, Ramirez-Campillo et al. (2020) demonstrated a soft surface produced longer ground contact times, causing slower stretch shortening cycle actions compared to hard surface. If frequently utilized in training, soft surface could result in different neuromuscular and musculotendinous adaptations compared to hard

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surface (Lesinski et al., 2017). While previous studies have examined various plyometric training surfaces, these studies utilized an athletic population and therefore the effects of training surface on a recreationally active population are unknown.

Examining how horizontal jump performance is impacted by the compliance of the plyometric training surface during training sessions can aid in offering potential variability for plyometric programs targeting specific training adaptions. This is important for coaches looking to enhance performance by utilizing alternative training areas based on the individual or team needs to help decrease muscle soreness and injury risk while producing different neuromuscular and musculotendinous adaptations. Therefore, the purpose of this study was to compare changes in horizontal lower body power in recreationally active individuals, as assessed by standing long jump (SLJ) performance, following a 6-week plyometric training program on a non-ridged, soft training surface (2-inch wrestling mat) and a ridged, hard training surface (hardwood gymnasium floor). It was hypothesized that training surface (soft surface versus hard surface) would not influence SLJ performance, as measured by distance.

METHODS

Study Design

This was a quasi-experimental study approved by the Middle Tennessee State University Institutional Review Board (IRB Approval #: 21-2173 4i). Participants volunteered and were required to read and sign an informed consent prior to participation. Participants also provided information on their history of plyometric training and lower limb musculoskeletal injury. The dependent variable was SLJ distance, and the independent variables were the soft and hard training surfaces.

Participant Characteristics

Twenty participants, 11 males and 9 females, participated in this study and were recruited from the university. The soft surface training group included five males and four females (age: 20.3 ± 1.7 yr; body mass 67.1 ± 7.2 kg; height 1.7 ± 1.7 m), while the hard surface training group included six males and five females (age: 21.2 ± 5.2 yr; body mass 70.3 ± 15.7 kg; height 1.7 ± 0.1 m). G*Power (version 3.1.9.4) was used to calculate a priori sample size and indicated that a power of 0.99 required 6 participants. To be included, participants needed to be physically active (participating in aerobic or anaerobic exercise at least 2 days a week for the past 3 months), free from lower limb musculoskeletal injuries (within the past 6 months), and not actively participating in any plyometric training program. Participants were excluded from the study if they did not meet the previously mentioned requirements.

Materials and Procedures

Participants were recruited by word of mouth. At the first session, participants read and signed the informed consent and completed the plyometric training, muscular skeletal injury, and physical activity history forms to determine if they met the inclusion criteria. Body mass was measured while participants were wearing athletic attire with shoes on prior to pre-testing using a digital scale (Tanita, Arlington Heights, IL, USA), and height was measured with shoes on using a stadiometer (SECA 222, Chino, CA, USA). Participants were instructed to wear athletic attire for all testing and training sessions. For pre-testing, participants completed a warm-up consisting of 10 repetitions of: jump rope, air squats, ankle hops, and countermovement jumps at a self-selected intensity with a 1-minute rest between each exercise. Following the warm-up, participants rested for 2 minutes, during which instruction was given to the participants on how to perform a SLJ. Participants were instructed to perform the jump using a bilateral stance for both take-off and landing, while swinging their arms and bending their knees to provide maximal horizontal propulsion forward. Participants were also instructed to have an approximate knee bend of 90 to 110 degrees for optimal performance (Ducharme et al., 2016; Wakai & Linthorne, 2005). Prior to testing, participants performed three submaximal SLJ with an arm swing. For testing, participants performed maximal SLJ separated by 30 seconds, until no improvement in performance was achieved. The best trial was used in data analysis and all testing trails were completed on a hardwood surface. The SLJ distance was measured in centimeters using a tape measure (Martin Sports, Carlstadt, NJ, USA) at the heel after landing.

Participants were assigned randomly to the soft surface or the hard surface training group, by counterbalancing sexes between groups upon entry into the study. The hard surface training group performed the training protocol on a wood gymnasium floor, while the soft surface training group trained on a 2-inch-thick wrestling mat placed over the gymnasium floor. Participants had a 2-week accommodation period to rule out neuromuscular adaptions as the primary source of increased SLJ distance (Lamas et al., 2012). During this time, participants performed the first 2 weeks of the training program to become familiarized with the training demands and were instructed on how to complete the program with proper form. Following the 2-week accommodation period, a post-accommodation pre-test for SLJ was performed and the best performance trial was used for the subsequent statistical analysis. Following the training program, participants performed their final post-accommodation test 48 hours following the last training session, testing was performed in the same manner as the pre-test and first post-accommodation pre-test.

Training Protocol

Participants agreed to maintain current exercise habits throughout the study. Each training group performed an identical mixture of plyometric exercises designed to increase lower body power (Table 1). The plyometric training program that was used in the current study was developed by Miller et al. (2007) and adopted by Sozbir et al. (2016). All participants performed two training sessions per week separated by 48 hours per training session for a total of 12 training sessions. Participants were allowed to miss two training sessions throughout the program. Participants were always under direct supervision during training. A 30-second break was taken between each set and a 1-minute break occurred between each exercise. Each session began with a warm-up that consisted of SLJ and ankle hops that covered 25 meters in distance, followed by 10 countermovement jumps. On average, the total duration of each session was 20 – 40 minutes. Participants performed their warm-up on the same surface as assigned for training.

Statistical Analysis

A Shapiro–Wilk normality test was performed to confirm the data were normally distributed. The Levene's test was performed to confirm data homoscedasticity. To determine possible baseline differences between groups, an unpaired t-test was performed. The mean differences for standing long jump distance were determined using a 2 (Training Surface: Soft and Hard) x 3 (Time: Pre-test, Post-accommodation, Post-test) repeated measure ANOVA. An alpha level of $p \leq 0.05$ was used to determine statistical differences. Significant interactions were decomposed with follow-up ANOVAs and post-hoc, Bonferroni corrected, paired t-tests (Weir, 2005; Wickens & Keppel, 2004). Effect sizes were reported as partial eta squared (η_p^2) and Cohen's d for the ANOVAs and pairwise comparisons, respectively. All statistical analyses were completed using IBM SPSS v. 28 (Armonk, NY, USA).

Table 1. 6-week plyometric training program protocol

	Volume (Foot Contacts)	Plyometric Exercises	Sets x Reps
Week 1	90	Lateral ankle hops	2 x 15
		CMJ*	2 x 15
		Front barrier jumps	5 x 6
Week 2	120	Lateral ankle hops	2 x 15
		SLJ	5 x 6
		Lateral barrier jumps	2 x 15
		Tuck jumps	5 x 6
Week 3	120	Lateral ankle hops	2 x 12
		SLJ	4 x 6
		Lateral barrier jumps	2 x 12
		Tuck jumps	3 x 8
		Lateral barrier jumps	2 x 12
Week 4	140	Diagonal barrier jumps	4 x 8
		SLJ with lateral sprint	4 x 8
		Lateral barrier jumps	2 x 12
		SLB**	4 x 7
		Side to side unilateral jumps	4 x 6
Week 5	140	Diagonal barrier jumps	2 x 7
		SLJ with lateral sprint	4 x 7
		Lateral barrier jumps	4 x 7
		Barrier jumps with half turn	4 x 7
		SLB**	4 x 7
		Side to side unilateral jumps	2 x 7
Week 6	120	Diagonal barrier jumps	2 x 12
		Hexagon drill	2 x 12
		Barrier jumps with directional sprints	4 x 6
		Tuck jumps	3 x 8
		Side to side unilateral jumps	4 x 6

*Counter movement jump

RESULTS

The data were normally distributed, and no significant differences were reported between the baseline analyzed variables ($p < 0.05$). The Shapiro-Wilks test was used to determine normality and showed that for all three time points the data were normally distributed ($p > 0.05$). Based on Levene's Test of Homogeneity of Variances (p > 0.05), there was not a significant difference in the homogeneity of variance between groups. The results of the repeated measures ANOVA for SLJ distance indicated that there was no significant interaction ($p = 0.914$; = 0.005) for the type of surface. There was, however, a significant effect for the intervention over time ($p = 0.000$; = 0.633), hence, the intervention was effective, independent of the surface type. The follow-up pairwise comparisons for SLJ distance indicated that Post-accommodation Post-test was significantly ($p = 0.000$; $d = 0.412$ to $d = 0.623$; Bonferroni corrected alpha = 0.0167) greater than both Pre-test and Post-accommodation Pre-test and Post-accommodation Pre-test was significantly ($p = 0.005$; $d = 0.265$) greater than Pre-test (Table 2).

DISCUSSION

The purpose of this study was to compare changes in horizontal lower body power, assessed by SLJ performance, following a 6-week plyometric training program on a non-ridged soft surface (2-inch wrestling mat) and a ridged hard surface (hardwood gymnasium floor). Both groups demonstrated statistically significant improvement in jump distance following training (soft surface = 7.3 % and hard surface = 5.1 %).

Examining how a hard surface and a soft surface can impact improvements from a plyometric training program can aid coaches in using varied surfaces to minimize injury, fatigue, and introduce variability into the training routine. The soft surface could have led to the improved SLJ distance due to an increase in the amortization phase allowing more time for force to be generated, compared to the hard surface where a shorter amortization phase would encourage neuromuscular components to enhance performance. Previously, Katkat et al. (2009) showed jumping performance was related to surface compliance, specifically, decreased

Table 2. Standing long distance (cm) by test and surface area type

Time Points	Hard Surface	Soft Surface
Pre-test	207.6±34.2	181.9±42.2
Post-accommodation Pre-test	216.1±25.4	191.6±34.6
Post-accommodation Post-test	227.2±23.4*	205.7±38.8*

* = Significantly greater than post-accommodation pre-test

surface compliance (asphalt) lead to a decrease in horizontal and vertical jumping performance. Whereas an increase in surface compliance (grass, Ethylene Propylene Diene Monomer, and Parquet) lead to an increase in leg stiffness and jump performance at a lower energy cost, leading to a decrease in muscle damage and fatigue. The different outcome from the current study is likely due to the hard surface (hardwood gymnasium floor) having more compliance than the asphalt surface used by Katkat et al. (2009).

Additionally, Arampatzis et al. (2004) performed drop jumps on to a hard and a soft sprung surface to examine which surface elicited greater jumping performance. The softer-sprung surface increased jumping height and energy cost compared to the hard-sprung surface, while there were no changes in leg and joint stiffness. The authors conjectured the increase in energy for the soft-sprung surface may have been due to an increase in ground contact time causing an increase in mechanical work during the eccentric and isometric phases of the jumps. Similarly, Jensen et al. (2010) showed horizontal jumps were longer on a soft surface. While Arampatzis et al. (2004) and Jensen et al. (2010) indicated surface compliance might play a bigger role in both the horizontal and the vertical components of jumping in acute testing, the same mechanical advantages on a soft surface or hard surface might play less of a role in producing significant increases in horizontal jumping performance long term.

The current results support prior research by Elvan et al. (2019). College-aged male volleyball players who participated in an 8-week plyometric training program, three days a week, on either a wooden surface or synthetic surface saw significant increases in horizontal power and jump distance on both surfaces. These results suggest alterations in training program variables of plyometric programs may play a greater role in altering changes in jump performance than training surface. Jensen and Ebben, (2007) observed similar acute results to the present study, in the horizontal direction, showing no changes in take-off velocity and jump height during plyometric exercises on hard or mat surfaces. The results of the current study and previous studies suggest there is no difference in the enhancement of the stretch-shorting cycle while training on hardwood or mat surfaces.

Soft surface and hard surface training have both been shown to increase horizontal jumping performance, however, a combination of training on both surfaces could lead to greater adaptations related to performance compared to training exclusively on one surface type. Ramirez-Campillo et al. (2020) found that for male youth soccer players, a midseason 8-week plyometric training program on various surfaces (i.e., grass, dirt, sand, gymnasium flooring, and track fields) brought greater changes in both vertical and horizontal jump performance compared to a plyometric training program on a single surface. These differences in performance may be due to the variety in training surfaces being more motivating and less redundant to the athletes, supporting greater effort during training (Ramirez-Campillo et al., 2020). While the present study did not assess training on a combination of surface areas, Lamas et al., (2012) determined training on a combination or single surface increased neuromuscular adaptations and horizontal jump performance.

Limitations

The current study exclusively examined the effects of training surface on a recreationally active college-aged population. It is, however, unknown whether the same outcomes will be evident across various training levels. As adaptation responses differ between a recreational population and an advanced athletic population, it is important to understand how training surface affects the outcome of plyometric training for an advanced population. Therefore, future studies should utilize various athletic populations to examine the effects of surface composition on plyometric training programs.

Strength and Practical Implication of Study

The results of the present study show that horizontal power performance can be improved with a plyometric training program, regardless of training surface composition. This could aid coaching professionals with developing plyometric training programs in situations where a variety of training surfaces may not be available.

CONCLUSION

The results of the present study indicated that the 6-week soft surface and hard surface plyometric training program in recreational young adults can enhance horizontal, lower body power. The comparison of surfaces did not reveal a statistically significant difference, which suggests that the training surface does not dictate the individual's horizontal power development, but rather the training program. Therefore, it is recommended that strength and conditioning coaches emphasize program and design to elicit sports specific adaptions based on the athlete's needs. Future studies should continue to examine the underlying physiological dimensions of plyometric training performed on different surfaces and how that may affect horizontal power development.

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