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Changes in Counter Movement Jump Height, Take-off Force and Maximum Concentric Power of Collegiate Athletes After Two Sessions Per Week Plyometric Training on Different Training Surfaces

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Abstract

Purpose: This study aimed to examine the effects of two sessions per week plyometric training on different surfaces on the counter movement jump height, take-off force, and maximum concentric power of collegiate athletes.

Material and methods: Male collegiate athletes (n=24, age=18.46±1.14 years, weight=64.88±5.61 kg and height=1.72±0.07 metres)) from a physical training centre were randomly and equally assigned to three groups, each trained on different surfaces (synthetic, cinder and sand). The training intervention was implemented twice a week and lasted for 8 weeks. The athletes were tested before and after the intervention to assess changes in the performance of counter movement jump height (CMJHT), take-off force (CMJTOF) and maximum concentric power (CMJMCP).

Results: Results showed that overall measurement of CMJHT, CMJTOF and CMJMCP improved significantly (p≤0.05, Δ %=10.50; p≤0.05, Δ%=11.11; p≤0.05, Δ%=11.41). However, training surfaces have no significant effect on the improvement of the selected variables (CMJHT:$F(2,21)=2.37$, $p=0.118$, $\eta_p^2=0.184$; CMJTOF:$F(2,21)=1.28$, $p=0.299$, $\eta_p^2=0.109$; CMJMCP:$F(2,21)=0.061$, $p=0.941$, $\eta_p^2=0.006$). Further, for the synthetic track surface group CMJHT, CMJTOF and CMJMCP improved significantly (p≤0.05, Δ%=16.36; p≤0.05, Δ%=17.50; p≤0.05, Δ%=17.99); for the cinder track surface group CMJHT and CMJMCP improved significantly (*p*≤0.05, Δ%=9.15; p≤0.05, Δ%=10.33) and for the sand surface group only CMJHT improved significantly (p≤0.05, Δ%=5.68).

Conclusions: The findings suggest that plyometric training on different surfaces can effectively improve athletic performance, but the specific surface type does not appear to impact the outcomes significantly. The study further suggested analysing the injury risk associated with plyometric training on various training surfaces and discovering the optimal training surface for minimising injury risk while maximising performance gains.

Keywords: counter movement, jump height, take-off force, maximum concentric power, plyometric, and training surface.

Анотація

Зміни показників висоти стрибка в протирусі, сили відштовхування та максимальної концентричної сили спортсменів-студентів після двох занять на тиждень плііометрічним тренуванням на різних тренувальних поверхнях. *Мета:* це дослідження було спрямоване на вивчення впливу двох занять пліометричним тренуванням на тиждень спортсменів-студентів на різних поверхнях на показники висоти стрибка в протирусі, сили відштовхування та максимальної концентричної сили. *Матеріали та методи:* спортсмени-чоловіки (n=24, вік=18,46±1,14 рік, вага=64,88±5,61 кг, зріст=1,72±0,07 м)) з центру фізичної підготовки були випадковим чином однаково розподілені три групи, кожна з яких тренувалася. на різних поверхнях (синтетика, бігова доріжка та пісок). Тренувальне заняття проводилося двічі на тиждень і тривало 8 тижнів. Спортсменів тестували до та після тренувального заняття для оцінки змін показників висоти стрибка у протирусі (ЗПСП), сили відштовхування (СВ) та максимальної концентричної сили (МКС). *Результати:*

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результати показали, що загальний вимір показників ЗПСП, СВ і МКС значно покращився (p≤0,05, Δ%=10,50; p≤0,05, Δ%=11,11; p≤0,05, Δ%=11 ,41). Однак тренувальні поверхні не мають істотного впливу на поліпшення обраних змінних (ЗПСП:F(2,21)=2,37, p=0,118, ηp2=0,184; СВ:F(2,21)=1,28, p=0,299, ηp2 = 0,109; МКС: F (2,21) = 0,061, p = 0,941, ηp2 = 0,006). Крім того, для групи з синтетичним покриттям показники ЗПСП, СВ і МКС значно покращилися (p≤0,05, Δ%=16,36; p≤0,05, Δ%=17,50; p≤0,05, Δ% =17,99); для групи на біговій доріжці показники ЗПСП, СВ і МКС значно покращилися (p≤0,05, Δ%=9,15; p≤0,05, Δ%=10,33), а для групи з піщаним покриттям значно покращилися тільки показник ЗПСП (p≤0,05, Δ%=5,68). *Висновки:* результати показують, що пліометричні тренування на різних поверхнях можуть ефективно покращити спортивні результати, але конкретний тип поверхні істотно не впливає на результати. У дослідженні також пропонувалося проаналізувати ризик травм, пов'язаний з пліометричними тренуваннями на різних тренувальних поверхнях, і знайти оптимальну поверхню для тренування для мінімізації ризику травм при максимальному підвищенні продуктивності.

Ключові слова: протирух, висота стрибка, сила відштовхування, максимальна концентрична сила, пліометрія, поверхня тренування.

Introduction

Plyometrics training is a method to enhance explosive strength. As coaches and players have realised the potential improvements it can bring to athlete performance, they have started including plyometric exercises in their general training and made it a key element in planning athletic development programmes. Apart from improving explosive strength, it is a very effective technique for building explosive power (Davies et al., 2015). It is based on the idea that rapid muscle lengthening just before contracting would increase the muscles' elastic strain energy, improving an athlete's ability to accelerate and start faster, change direction more quickly, and increase overall speed (Davies et al., 2015). In addition, it provides a great deal of variation regarding exercises and load designing. Voluntary and involuntary muscular contractions are both included in plyometric training. As a result, many motor units are engaged during a single contraction, increasing an individual's motor coordination (Chimera et al., 2004). Concentric contraction occurs immediately following the eccentric contraction in plyometric activities (Behrens et al., 2016). Stretch-shortening is a process that combines eccentric (muscle lengthening) and concentric (muscle shortening) actions (Behrens et al., 2016). When an athlete drops his or her weight, an eccentric muscle movement occurs; when the athlete lifts his or her weight, a concentric muscle movement occurs (Aboodarda et al., 2015; Behrens et al., 2016). When an eccentric action follows a concentric action, the equivalent force output of the concentric action is enhanced (Aboodarda et al., 2015). This stretch-shortening acts similarly to an extended rubber bend and aids in the execution of the movement accordingly.

The effectiveness of plyometric exercises can vary based on the intensity, volume and selection of exercises (Davies et al., 2015). That is why the individuals performing plyometrics should understand how to work out, execute, and modify the programme to maximise its effectiveness. However, the volume, intensity, or type of exercise do not always influence plyometric exercise effects. Many researchers were concerned about the combined effect of plyometric exercises and training surfaces. Among them, Ramirez-Campillo et al. (2018) reported that using moderate plyometric exercise volume on a hard surface can significantly increase reactive strength. Whereas Ozen et al. (2020) found that plyometric exercises on wooden or sand surfaces had not caused any differences in improving jumping performance. However, another research further indicated that sand training might be more effective in developing speed and agility among young athletes, and a similar result was also reported by Hammami et al. (2020) in a different study. Another study Çimenli et al. (2016) reported the significant effect of plyometric training on the jump performance of volleyball players but rejected the idea of different training effects of plyometric exercises in two different training surfaces (wooden and synthetic). Although research had established that athletes' performance could also be affected by environmental factors like playing surfaces (Ozen et al., 2017), no study had directly investigated the effect of plyometric exercises on three different training surfaces (i.e., Synthetic Track Surface, Cinder Track Surface and Sand Surface). Since the compositions of different training surfaces differ significantly and may affect not only speed, endurance and balance but also the technique. Therefore, it is very important to understand how plyometric training can affect differently on different training surfaces.

Coaches and researchers commonly use the Counter Movement Jump (CMJ) test as an indirect method to assess the explosive power output of the lower body of an individual (Petrigna et al., 2019). In most cases, the performance of the CMJ is measured in terms of jump height or relative peak power output. However, other variables like Take off Force, Impact Force, Maximum Concentric Power, Average Speed Concentric Phase, Peak Speed, Take Off Speed etc., can also be measured using specialised equipment like Force Platform, Accelerometer, High-Speed Camera etc. Many studies have examined the direct effect of plyometric training on CMJ jumping ability, ground reaction forces, isokinetic forces, take-off force, take-off velocity, power etc. (Borah & Sajwan, 2022; Correia et al., 2020; Ismail et al., 2014; Matavulj et al., 2001; Ramirez-Campillo et al., 2021; Stojanović et al., 2017), and reported their individual results and conclusions. However, very few studies have investigated the effect of plyometric training on the performance of the CMJ test in different training surface settings.

The purpose of the study: Therefore, the current study was conducted to investigate the effect of plyometric training on selected CMJ variables of collegiate athletes on three different training surfaces (Synthetic Track Surface, Cinder Track Surface and Sand Surface). In this study, the performance of CMJ test was tested on three variables, i.e., CMJ height, CMJ take-off force and CMJ maximum concentric power.

Material and Methods of the research

Participants

The participants were selected from a physical training centre, which trains collegiate sportspersons for competitions as well as to participate in various competitive examinations which required physical fitness tests. The minimum sample size was determined using the software "G*Power Version 3.1.9.2." (Verma & Verma, 2020); according to which a minimum of eighteen (18) samples were required to obtain a large effect with predetermined power of 80% and alpha 5%. However, keeping in mind the potential participants attrition and the result of the sample size determination test, a total of twenty-four (N=24) participants (age=18.46±1.14 years, weight=64.88±5.61 kg and height=1.72±0.07 metres) were randomly selected for the study. Furthermore, the participants were equally and randomly (8 participants in each group) assigned to three different training surface groups; i.e., Synthetic Track Surface group, Cinder Track Surface group and Sand Surface group.

Experimental design

A two-factorial design was adopted as the experimental design for the study. The first factor was "Surface Type" and the other factor was "Training Duration." The "Surface Type" factor had three levels of measurements comprising three types of training surfaces while the other factor "Training Duration" had two levels of measurement, i.e., pre-test and post-test. The participants were trained with two sessions of plyometric training per week. The training sessions were distributed as per the schedule mentioned in Table 1. Furthermore, the training sessions were maintained throughout the duration of eight (8) weeks. The training sessions were designed as per the recommendation from Bedoya et al. (2015) and Çimenli et al. (2016). The training sessions started with 10 minutes of warm-up exercises, and 35-45 minutes of plyometric exercises and ended with 10 minutes of cooling-down exercises (sample training schedule: Table 2). With the progression of duration, the volume, intensity and frequency of the exercises also increased as per the suggestions from Bedoya et al. (2015) and Çimenli et al. (2016). The pre-test was conducted two days before the start of training sessions and was completed in a single day. While the post-test was conducted two days after the completion of eight (8) weeks of training sessions separately for each training surface group. The effect of fatigue was presumed nil based on the finding of Monteiro et al. (2019). The overall flow of the study can be understood using the Figure 1.

Testing equipment

The tests for data collection were administered inside the sports biomechanics laboratory of Lakshmibai National Institute of Physical Education, Gwalior, India. To collect data, BTS G-WALK® system was used (BTS Bioengineering S.p.A., Italy). The whole system comprised of a device named 'G-Sensor' and a dedicated software named 'G-Studio'. The system is a highly reliable and valid tool for measuring gait and jump parameters (Gogoi, Borah, et al., 2021; Gogoi, Rajpoot, et al., 2021).

Testing protocol

To analyse specific movements, specific protocols were prescribed in the manual of BTS G-WALK® system. The current study was also conducted following the mentioned protocols; according to which the G-Sensor device was placed at the

Table 1. Schedule of training sessions

Day	Training group
Monday	X
Tuesday	Y
Wednesday	Z
Thursday	X
Friday	Y
Saturday	Z

X: Synthetic track surface
Y: Cinder track surface
Z: Sand surface

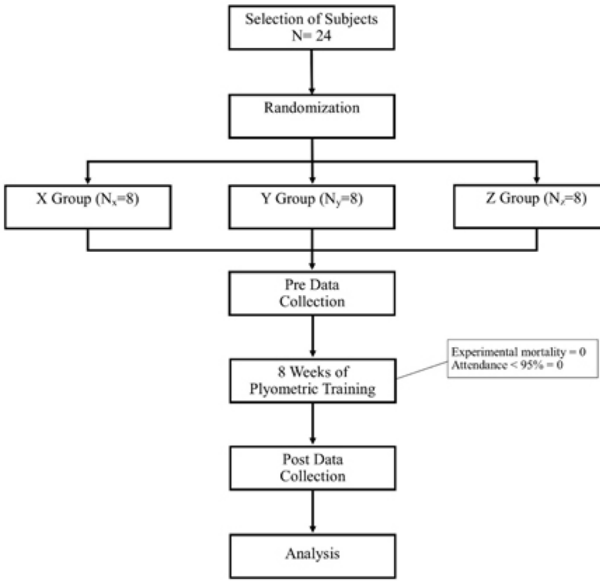

Figure 1. Experimental Design

Table 2. Sample training program

Exercise		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Hurdle hopping		2×10		2×10	3×10		3×10		3×10
Single leg hopping			2×10			3×10		3×10	
Box jump			2×10			3×10		3×10	3×10
Depth jump				2×10	3×10		3×10		
Tuck jump		2×5		2×10			2×10	2×10	
Bunny hops		2×10				3×10		3×10	3×10
Single leg stair				2×10			3×10		3×10
Squat jump				2×10	3×10			3×10	
Poggo hopping			2×10			3×10			3×10
Lateral hops		2×10				3×10	3×10	3×10	
Ankle jumps			2×5		2×10		3×10		3×10
Power skipping			2×10	2×10		3×10		3×10	
Jumping lunge		2×10			3×10		3×10		3×10
Total Volume		90 FC	90 FC	120 FC	140 FC	180 FC	200 FC	200 FC	210 FC
Recovery	R	30 sec	30 sec	30 sec	30 sec	20 sec	20 sec	20 sec	20 sec
	S	120 sec	120 sec	100 sec	100 sec	100 sec	100 sec	90 sec	90 sec

FC: Foot contact
R: Repetition
S: Sets

back, in line with two dimples of Venus - lumbosacral passage, which corresponds to S1-S2 vertebrae of the human body. To perform CMJ the subjects stood in an upright position with feet apart according to shoulder width and hands on hip. Then the subject jumped on the command of start by the operator, after doing a countermovement downward action by bending their knees up to 90^0. Using the software G-Studio, the required data were generated after the completion of the CMJ action of the subject. The execution of CMJ was also demonstrated by the researcher to the subjects and a familiarisation session was conducted before the commencement of the actual test.

Variables

The dependent variables: the 'Countermovement Jump Height (CMJHT)' is defined as the highest point that the athlete can reach during the execution of a countermovement jump and was measured in the unit centimetre (cm), the 'Countermovement Jump Take-off Force (CMJTOF)' is defined as the measure of the maximal force generated by an individual's lower body during a countermovement jump test (Muraki et al., 2008) and was measured in the unit kilonewton (kN), and the 'Countermovement Jump Maximum Concentric Power (CMJMCP)' is a measure of an individual's maximal power output during a countermovement jump test (Hody et al., 2019) and the unit of measurement was kilowatt (kW).

Statistical analysis

The Normality assumption of the data was tested employing Shapiro-Wilk statistics, the Homogeneity of Variance Covariance Matrices assumption was tested using Box's M test, the equality of error variances assumption was tested by using Levene's Test, and the Sphericity assumption was tested by applying the Mauchly's W test. All the assumptions were verified independently by two of the authors and found satisfactory. In descriptive statistics, mean and standard deviation were displayed. To test the hypothesis of the study; the two-way ANOVA test was applied to test the main effect of both within and between-subject factors. Paired t-test was applied to check the difference between pre and post test measurements for every variable separately for different training surfaces. In addition, the partial eta-squared test was performed to calculate the test's effect size. All statistical tests were conducted using Statistical Package for Social Sciences (SPSS), version 25.00 (Armonk, 2017) and tested at the significance level of 0.05 ($p<0.05$).

Ethics

The study was a part of a doctoral-level study, and the institute's departmental research committee approved the proposal (No. Academic/Ph.D./379/1294). The study was conducted following the latest guideline mentioned in the Declaration of Helsinki (World Medical Association, 2013). The participants were fully informed about the purpose of the study, the detailed experimental design, and potential risks and benefits before registering for the study. All participants voluntarily agreed and gave written consent to participate in the study. The participants were also given the right to withdraw from the study at any time if they felt so.

Results of the research

The results (table 3) of the study revealed that for the measurements of all the dependant variables, the F value for the within-subject factor 'Training Duration' (main effect) was significant (CMJHT: $F(1, 21)=50.45$, $p=0.000$, $\eta_p^2=0.706$; CMJTOF: $F(1, 21)=10.25$, $p=0.004$, $\eta_p^2=0.328$; CMJMCP: $F(1, 21)=11.11$, $p=0.03$, $\eta_p^2=0.346$) which indicates that the main effect of 'Training Duration' is meaningful and significant at the level of 5% with large effect size ($\eta_p^2 \geq 0.14$). Hence, it can be said that there were significant differences among measurements of pre and post training for all the variables irrespective of the factor training surface. Further, the pairwise comparison reveals that the overall CMJHT of all three training surface groups increased significantly from the pre-test to the post-test and the percentage change was 10.50 ($p\leq0.05$, Δ %= 10.50). For the variable CMJTOF, the overall measurement increased significantly from the pre-test to the post-test and the percentage change was 11.11 ($p\leq0.05$, Δ %= 11.11). A similar trend was also observed for the variable CMJMCP, which indicates that the overall measurement increased significantly from the pre-test to the post-test and the percentage change was 11.41 ($p\leq0.05$, Δ %= 11.41).

The results also revealed that the F value for the between-subject factor 'Training Surface' (main effect) is not significant (CMJHT: $F(2, 21)=2.37$, $p=0.118$, $\eta_p^2=0.184$; CMJTOF: $F(2, 21)=1.28$, $p=0.299$, $\eta_p^2=0.109$; CMJMCP: $F(2, 21)=0.061$, $p=0.941$, $\eta_p^2=0.006$) which indicates that there is no difference of mean scores of measurements for all the variables for different training surface irrespective of the factor time duration. The results also indicate that the F value for the interaction (Time Duration × Training Surface) for the variable CMJHT is significant and meaningful (CMJHT: $F(2, 21)=5.16$, $p=0.015$, $\eta_p^2=0.329$) with large effect size ($\eta_p^2 \geq 0.14$). But, for the other two variables, i.e., CMJTOF and CMJMCP; (CMJTOF: $F(2, 21)=3.11$, $p=0.066$,

Table 3. Statistical test results to test the main effect and simple effect of the independent variables on the dependent variables with pairwise comparisons

Variables		Synthetic track surface (N=8)	Δ %	Cinder track surface (N=8)	Δ %	Sand surface (N=8)	Δ %	Overall	Δ %	ANOVA Results		
										Training Surface ($F(2, 21)$ =value, p=value, η_p^2= Partial Eta Squared)	Training Duration ($F(1, 21)$ =value, p=value, η_p^2= Partial Eta Squared)	Training (Training Surface×Training Duration $F(2, 21)$ =value, p=value, η_p^2= Partial Eta Squared)
CMJHT	Pre	27.35±3.94	16.36*	26.10±2.26	9.15*	25.94±2.30	5.68*	26.46±2.88	10.50*	$F(2, 21)=2.37$, $p=0.118$, $\eta_p^2=0.184$	$F(1, 21)=50.45$, $p=0.000$, $\eta_p^2=0.706$	$F(2, 21)=5.16$, $p=0.015$, $\eta_p^2=0.329$
	Post	31.83±3.21		28.49±3.53		27.41±2.13		29.24±3.46				
CMJTOF	Pre	0.71±0.25	17.50*	0.68±0.26	5.87	0.90±0.29	2.00	0.76±0.27	11.11*	$F(2, 21)=1.28$, $p=0.299$, $\eta_p^2=0.109$	$F(1, 21)=10.25$, $p=0.004$, $\eta_p^2=0.328$	$F(2, 21)=3.11$, $p=0.066$, $\eta_p^2=0.228$
	Post	0.88±0.28		0.74±0.17		0.92±0.25		0.85±0.24				
CMJMCP	Pre	2.44±0.62	17.99*	2.57±0.42	10.33*	2.67±1.00	6.45	2.56±0.69	11.41*	$F(2, 21)=0.061$, $p=0.941$, $\eta_p^2=0.006$	$F(1, 21)=11.11$, $p=0.03$, $\eta_p^2=0.346$	$F(2, 21)=0.79$, $p=0.465$, $\eta_p^2=0.070$
	Post	2.88±0.52		2.83±0.29		2.85±0.61		2.85±0.47				

#: Sphericity assumed.
*: The mean differences are significant at the 0.05 level.

η_p^2=0.228; CMJMCP: $F(2, 21)$=0.79, p=0.465, η_p^2=0.070) no significant interaction was found (p>0.05). Since significant interaction was found for one of the variables, therefore simple effects were required to be checked to explore the exact nature of the interaction. The testing of simple effect using paired t-test revealed that for the Synthetic Track Surface group; the CMJHT improved significantly and the percentage change was 16.36 (p≤0.05, Δ %= 16.36), the CMJTOF improved significantly and the percentage change was 17.50 (p≤0.05, Δ %= 17.50) and the CMJMCP improved significantly and the percentage change was 17.99 (p≤0.05, Δ %= 17.99). The testing of simple effect for the Cinder Track Surface group revealed that the CMJHT of the group improved significantly and the percentage change was 9.15 (p≤0.05, Δ %= 9.15) and for the variable CMJMCP, the significant percentage change was 10.33 (p≤0.05, Δ %= 10.33). However, for the variable CMJTOF, even though a 5.87 per cent improvement was reported, it was not significant (p>0.05, Δ %= 5.87). The testing of simple effect for the Sand Surface group revealed that the CMJHT of the group improved significantly and the percentage change was 5.68 (p≤0.05, Δ %= 5.68). However, even though the variables CMJTOF and CMJMCP exhibited 2% ((p>0.05, Δ %=2.00) and 6.45% (p>0.05, Δ %=6.45) improvement respectively, the improvement was not significant (p>0.05).

Discussion

The main experiential result of this investigation is that two sessions per week plyometric training has significant and large effect on the improvement of countermovement jump height, take-off force and maximum concentric power of collegiate athletes, however training surfaces have no significant effect on the improvement of the selected variables.

The increase in countermovement jump height after plyometric training can be attributed to several physiological adaptations, including increases in muscle power and neuromuscular efficiency (Vissing et al., 2008). Plyometric exercises, characterised by explosive, high-intensity movements, are known to enhance muscle strength, power, and elasticity, enabling greater force production during jumping tasks (Davies et al., 2015). Studies have shown that plyometric training can enhance muscle power through increased muscle cross-sectional area (Grgic et al., 2021) and muscle fiber type transformation (Plotkin et al., 2021) towards a more power-oriented fiber type (Fast Twitch Type II fibers). This can lead to a higher muscle power output, resulting in a greater jump height. The high-intensity, explosive jumping movements performed in plyometric exercises place significant demands on the muscles and nervous system, leading to adaptations in both strength and power (Chimera et al., 2004; Martin, 2020). These adaptations can increase the amount of force that can be produced during jumping movements, thereby increasing countermovement jump height. Furthermore, repeated practice of these movements can improve the coordination and reaction time of the muscles and nervous system (Chimera et al., 2004; Davies et al., 2015). This is a result of increased muscle activation, synchronisation, and firing rates during plyometric exercises, further contributing to improved jumping performance. Recent research by Kosova et al. (2022) and Voisin & Scohier (2019) also supports these findings, as they found that plyometric training program resulted in significant improvements in jump performance.

Numerous studies have demonstrated the positive effects of plyometric exercises on counter movement jump related factors (Kons et al., 2023). Study conducted by Ita & Guntoro (2018) and Singh et al. (2018) reported that plyometric training significantly improved muscle power in trained athletes. Other studies by Chimera et al. (2004) and Vissing et al. (2008) reported that plyometric training significantly improved neuromuscular efficiency in untrained individuals. This type of training has been shown to enhance the mechanical and neural aspects of muscle performance, as well as increase muscle activation, leading to greater muscle power output during jumping movements and result in increased efficiency in the muscle activation patterns during a countermovement jump, leading to an increase in take-off force. That may the reason behind the result of the current study which revealed that two sessions per week plyometric training improves countermovement take-off force of collegiate athletes.

Studies have also shown that the adaptations in muscle power and neuromuscular efficiency resulting from plyometric training can result in significant improvements in maximum power output of the lower body (Makaruk & Sacewicz, 2010). Ramirez-Campillo et al. (2018) reported that plyometric training resulted in significant improvements in maximum concentric action related movements in male soccer players. In the present study, it was observed that the high-intensity, explosive movements of plyometric exercises might have increased muscle strength, power, and elasticity, while repeated practice improves neural pathways responsible for coordinating muscle contractions. These adaptations result in improved coordination, control, and power during movements, leading to an increase in maximum concentric power of the lower body.

The training surface has been a topic of discussion in the field of plyometric training and its impact on jump performance. A number of studies have investigated the effect of different training surfaces, such as grass, artificial turf, and rubberised surfaces etc., on jump performance (Çimenli et al., 2016; Lännerström et al., 2021; Marzouki et al., 2022; Ojeda-Aravena et al., 2022; Ramlan et al., 2018; A. Singh et al., 2014). Ramlan et al. (2018) compared the effects of plyometric training on grass and concrete surface on jump performance of volleyballers. They found that plyometric training on both surfaces resulted in similar training-induced effects on neuromuscular factors. Another study by Singh et al. (2014) reported no significant difference in jump performance between plyometric training on sand and grass surface in field hockey players. There is some evidence in the literature that suggests that the type of training surface may have an impact on injury risk during plyometric training (Impellizzeri et al., 2008; A. Singh et al., 2014). According to study by Hatfield et al. (2019); Wannop et al. (2020) and Yasamin et al. (2017), landing forces were higher on a synthetic turf surface compared to a natural grass surface. This finding suggests that synthetic turf may increase the risk of injury during plyometric exercises, as the higher landing forces can place greater strain on the joints and muscles. Similarly, a study by Ebben et al. (2010) found that performing plyometric exercises on a soft surface, such as a gymnastics mat, resulted in lower ground reaction forces and impact loading compared to a hard surface, such as a concrete floor. The authors suggest that performing plyometric exercises on a soft surface may help reduce the risk of injury, as the lower impact forces reduce the strain on the joints and muscles. Overall, the scientific literature suggests that the type of training surface does not have a significant effect on the improvement of jump-related variables after plyometric training, however the variations in training surfaces have significant relationship with injury occurrences. The improvement in jump performance is largely dependent on the intensity and specificity of the plyometric exercises and the individual's training status and adaptations (Ramírez-Campillo et al., 2013). It was concluded that the training surface may not dictate the improvement of jump-related variables after plyometric training, and individuals can choose the training surface that suits their preferences and training goals. For the present study also similar result is observed, which indicates that there is no significant effect of training surface on improvement of the selected variables irrespective of the factor time duration.

Conclusions

The study concluded that two sessions per week of plyometric training significantly improved countermovement jump height, take-off force, and maximum concentric power in collegiate athletes. The improvement was attributed to increased muscle power and neuromuscular efficiency resulting from high-intensity, explosive movements and improved coordination, control, and power during movements. The study also found that variations in training surfaces does not significantly impact the improvement of the selected jump-related variables after plyometric training. However, researchers recommend that future studies should be conducted to evaluate the injury risk associated with plyometric training on different types of training surfaces and identify the most suitable surface for minimising injury risk while maximising performance benefits. It was also opined that further research is needed to identify the most effective plyometric exercises for specific athletic performance goals and to optimise exercise prescriptions for different populations.

Author's contribution

Poli Borah- study design/planning, data collection/entry, manuscript preparation, literature analysis/search;

Lakshyajit Gogoi- study design/planning, data collection/entry, manuscript preparation, literature analysis/search;

Hemantajit Gogoi- study design/planning, data collection/entry, data analysis/statistics, data interpretation, manuscript preparation, literature analysis/search, fundraising;

Karuppasamy Govindasamy- manuscript preparation, literature analysis/search, fundraising;

Sambhu Prasad- manuscript preparation, literature analysis/search, fundraising;

Tadang Minu- manuscript preparation, literature analysis/search, fundraising;

Koulla Parpa- manuscript preparation, literature analysis/search, fundraising;

Abderraouf Ben Abderrahman- manuscript preparation, literature analysis/search, fundraising.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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