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Effectiveness of Plyometric Drills on Peak, Average and End Anaerobic Power in Trained and Untrained Individuals

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Abstract

Understanding how to optimize training for every individual is the goal for all exercise specialists. The current study looked into the effects of plyometric development drills within differently trained populations on anaerobic peak power, average power, end power, and fatigue index. **Purpose:** This research was intended to explore the potential for untrained individuals to benefit positively from plyometric training in peak power, end power and average power proportionally equal to trained individuals. **Methods:** Participants were recruited both verbally and electronically. Recruited participants (n = 11, age = 21.3 ± 0.6 years, weight = 69.4 ± 15.0 kg, height = 170.3 ± 9.2 cm, body fat = 20.2 ± 5.8%) attended a total of three sessions. Participants were separated into two groups: trained or untrained. Training status was defined as completing at least two sessions a week of resistance training for at least 20 minutes each session, for 12 continuous weeks prior to participating. All participants completed two 30 second Wingate tests (WAnT) to test peak power, average power, end power and fatigue index. One test was preceded by a dynamic warm-up and plyometric drills (Plyos), while the control only included the dynamic warm-up (No Plyos). **Results:** Multiple mixed-method analysis of variances (ANOVA) were conducted using SPSS. It was found that the use of plyometrics significantly increased peak power ($F_{1,9}$ = 13.07, $p < 0.05$, Plyos =959.6 ± 245.9 W, No Plyos = 884.5 ± 235.6 W) and anaerobic capacity ($F_{1,9}$ = 5.37, p = 0.046, Plyos = 7.78 ± 1.513 W/kg, No Plyos = 7.436 ± 1.507 W/kg). In contrast, average power ($F_{1,9}$ = 3.98, $p > 0.05$) and end power ($F_{1,9}$ = 0.08, $p > 0.05$) were not significantly affected. **Conclusion:** Plyometrics prior to power testing improved peak power performance for both trained and untrained individuals.

Key Words: Plyometrics, Wingate, Training Status

Introduction

The fitness industry is a massive market that is continuing to grow every single year. As of 2019, Business Insider® estimated the global fitness industry worth an estimated $100 billion dollars (Biron, 2019). This level of influence has caused all population types to become increasingly more involved in health and wellness. Each population brings its own goals and obstacles, making training very flexible, allowing for different experiences for each person. Therefore, it is crucial that exercise specialists understand how to best treat each population specifically to achieve individual goals and promote good health and performance, as training protocols may affect various populations differently (Gil, 2019).

Plyometrics can be used effectively by all populations when properly instructed and practiced. They are a very effective training modality, which have been shown to increase an individual's power output (Luebbers 2003). Plyometrics induce physiological responses such as, improving rate of force development (RFD), or the speed at which contraction can occur (Lorenz 2011). Plyometrics also develop the stretch-shortening cycle and the muscle's ability to work quickly. The stretch-shortening cycle involves the enhanced contraction force of muscle following a brief stretch stimulus, which can be a useful mechanism that all training populations can use to their advantage (Flanagan 2008). Plyometrics elicit the response of the muscle's capacity to contract concentrically after an eccentric load. As Chimera et al. (2004), found that plyometrics in female athletes is associated with an improved stretch response of muscles due to golgi tendon organ manipulation. Golgi tendon manipulation increases muscle length, eliciting a greater force production concentrically after the eccentric phase of the plyometric exercise (Chimera 2004). Untrained individuals may seek methods such as this to improve their own performance or response to planned exercise. Further understanding how to efficiently use tools such as plyometrics to elicit positive changes in all populations is crucial for good strength and conditioning.

Therefore, the purpose of this study was to examine the effects of utilizing an acute set of plyometric drills within trained and untrained populations, and observing any power performance changes. Performance variables including: peak power, average power, end power and fatigue index were measured during a Wingate test (WAnT). The WAnT is a commonly used performance measurement, which determines an individual's anaerobic performance capacity (Franco 2012). It is hypothesized that trained individuals will experience greater WaNT performance than untrained individuals following pre-exercise plyometrics. It is also hypothesized that both groups will significantly increase WanT measured peak power, average power and end power readings in their pre-exercise plyometric testing session.

Methods

Seven females (21.3 ± 0.8 years, 60.3 ± 7.6 kg, 166.3 ± 5.5 cm) and four males (21.3 ± 0.5 years, 85.5 ± 9.7 kg, 177.2 ± 10.9 cm) volunteered from the University of Lynchburg by way of email and oral recruitment methods. Each participant was screened for physical activity readiness through the use of the Physical Activity Readiness Questionnaire + (PAR-Q+) (Bredin 2013). All participants were then separated into two groups depending on their previous training experience. Status of training was defined by resistance training at least twice a week for the past 12 weeks to be considered trained (Buckner 2017). A total of four participants (n=4) were placed in the trained individuals group (TI). The remaining seven participants (n=7) were then placed in the untrained individuals group (UI). All methods of recruitment and experimental procedures were reviewed and approved by the Institutional Review Board of the University of Lynchburg.

Protocol

The research was based on three separate sessions that the participants were required to attend. All sessions were completed in a controlled laboratory setting to eliminate confounding external factors. The first of which was a basic foundational session, where the participant's demographic information was gathered, and overall procedure and equipment were introduced. Age, sex, height and weight were all measured accordingly. This information would then be used to conduct body composition measurements using a bioelectrical impedance analysis device (Omron HBF-306C, Kyoto, Japan). Participants were also familiarized with the different levels of the Borg Rate of Perceived Exertion (RPE) scale, and how to categorize their perceived efforts effectively (Borg 1982). The participants were guided to ensure that all documents were filled out correctly, and all questions were answered. Proficiency in all plyometric drills, including Ankling, A-Skips, and Broad Jumps (Appendix 1) were demonstrated and instructed during this session by the student researcher, to ensure that there would be limited confounding factors regarding familiarization for the two testing sessions. Participants were allowed to practice the different drills until they felt comfortable performing each one individually. The testing sessions were randomly organized so neither the researcher nor the participant were aware of which session they would complete first. At least 72 hours separated the two testing sessions within a two-week time frame of starting the first testing session.

The control session (CS) included a standard warm-up that would be used in both sessions. For the standard warm-up, the participant completed 5 minutes of jogging on a treadmill at a self-selected speed. A series of dynamic stretches was performed including: dynamic pigeon, leg swings, fire hydrant circles, and frog walk-ins with a twist, all for two sets of eight repetitions per side. The participant was allowed to spin on a cycle ergometer against zero resistance if additional warm-up was needed. Upon completing this standard warm-up, participants then performed a standard WAnT (Zupan 2009). The participant used the Velotron cycle ergometer (RacerMate; Seattle, WA) to begin the test. Instructions were given to pedal, gradually increasing the number of revolutions per minute against no resistance. Upon the end of a ten-second countdown, the participant was instructed to be at maximum revolutions per minute. The resistance was then added to the bike electronically equal to 7.5% of the participant's body weight. Measurements of Peak Power (PP), End Power (EP) and Average Power (AP) were taken electronically for the next 30 seconds. Secondary measurements of Aerobic Capacity, Aerobic Power, and Fatigue Index were also calculated. Once completed, the resistance was lifted and the participant slowly reduced their revolutions per minute until coming to a stop. The WAnT was completed and a rate of perceived exertion was assessed using the Borg model (Borg 1982) to assess the participant's exertion during the test. Participants were then instructed to continue pedaling against minimal resistance on a separate cycle ergometer at least until their heart rate returned to below 120 beats per minute.

The experimental session (ES) included the use of plyometric movements to be completed after the standardized warm-up to induce potential increases in muscle performance. Ankling, A-Skips and Broad jumps were all selected to target functionality of the used muscle groups during a WAnT and still maintain a level of easy instruction for any participant that was not familiar with these exercises prior to testing. Broad jumps and A-Skips were selected due to their ability to properly stretch muscles of the lower extremities to induce a stretch-shortening response on the eccentric phase of the movement (Rimmer 2000). As a response, it was predicted that these plyometrics would have a direct positive effect on WAnT performance. Each exercise was also reviewed and practiced during the informational sessions to ensure the most effective form was utilized during the exercises. Both Ankling and A-Skips were completed for two sets of 40m. The participants were then instructed to complete one set of 5 broad jumps, and were then led through the same WAnT procedures as conducted during CS testing.

Statistical Analysis

A mixed-method analysis of variance (ANOVA) was conducted using SPSS, version 26 (Chicago, IL) and JASP 12.2 (Amsterdam, Netherlands) for the dependent variables: peak power, end power, average power, time to peak power, anaerobic capacity, anaerobic power, fatigue index, and RPE. A Bonferroni post hoc analysis was performed following significant interactions. Statistical significance was set *a priori* at 0.05.

Results

Eleven participants volunteered for the study. Four trained (21.3 ± 0.5 years, 69.6 ± 17.4 kg, 178.0 ± 11.0 cm, and 14.4 ± 5.3 percent body fat) and seven untrained (21.3 ± 0.8 years, 69.4 ± 15.0 kg, 165.9 ± 4.2 cm, and 23.6 ± 2.3 percent body fat) participants completed the study (Table 1).

Table 1 Participant Demographics (N=11)

		n	%					
Sex	Male	4	36.4					
	Female	7	63.6					
	Age (years)		Height (cm)		Weight (kg)		Body Fat (%)	
	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained
Mean	21.3	21.3	178	165.9	69.6	69.4	14.4	23.6
SD	0.5	0.8	11.0	4.2	17.4	15.0	5.3	2.3
Range	21-22	20-22	164-189	158-171	53.1-91.7	53.2-95.5	7.4-20	20.1-26.5

Peak Power. Performing plyometric drills as a part of the warm-up significantly increased the peak power of participants during WAnT (Fig. 1, $F_{1,9} = 13.07$, $p = 0.006$). Between the trials, plyometrics (970.6 ± 268.9 W) was higher than no plyometrics (889.3 ± 262.5W) for peak power. The activity level of the participants did not significantly affect peak power ($F_{1,9} = 0.138$, $p > 0.05$) and a significant interaction between trial type and activity level was not found ($F_{1,9} = 1.01$, $p > 0.05$).

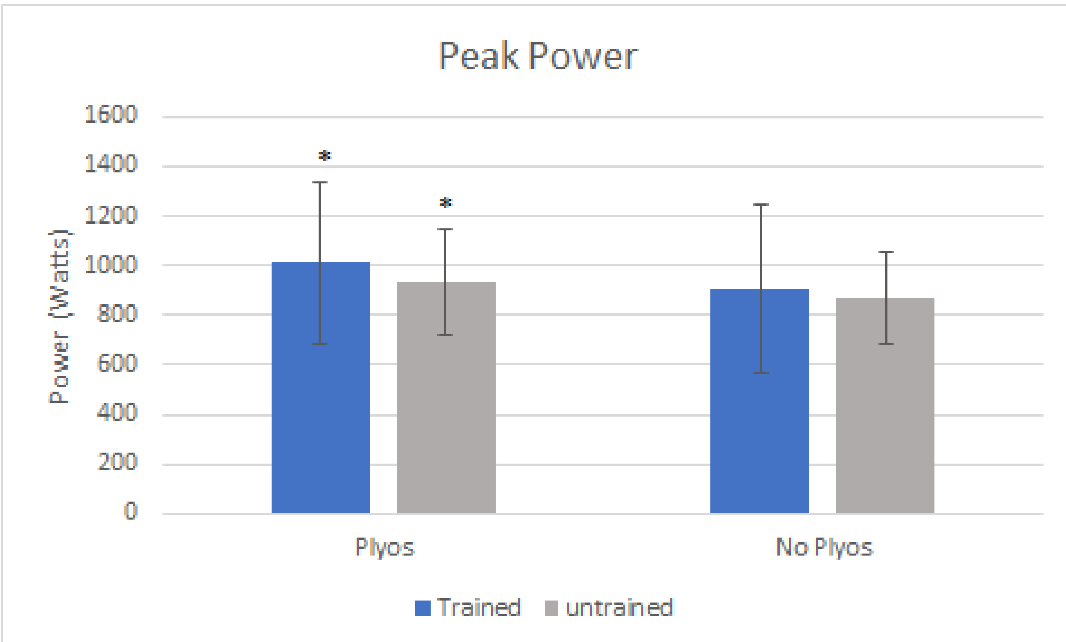

Figure 1. Peak Power between plyometric and no plyometric trials. * p<0.05 between no plyos

End Power. Performing plyometrics did not significantly affect end power ($F_{1,9} = 0.08$, $p > 0.05$). There were also no significant differences found between different activity levels ($F_{1,9} = 3.97$, $p > 0.05$) nor was there a significant interaction between activity level and trial type (Fig.2, $F_{1,9} = 0.02$, $p > 0.05$).

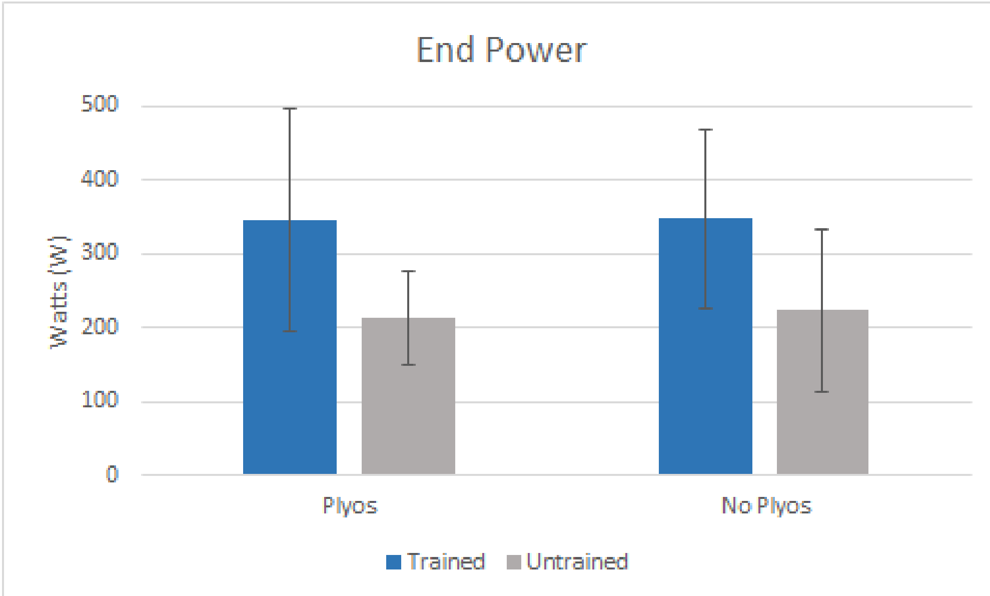

Figure 2. End Power between different trials and activity levels

Average Power. Performing plyometrics did not significantly affect average power ($F_{1,9}$ = 3.98, $p > 0.05$). There were also no significant differences found between different activity levels on average power ($F_{1,9}$ = 1.76, $p > 0.05$), nor were there any significant interactions between activity levels and trial types on average power (Fig.3, $F_{1,9}$ = 0.05, $p > 0.05$)

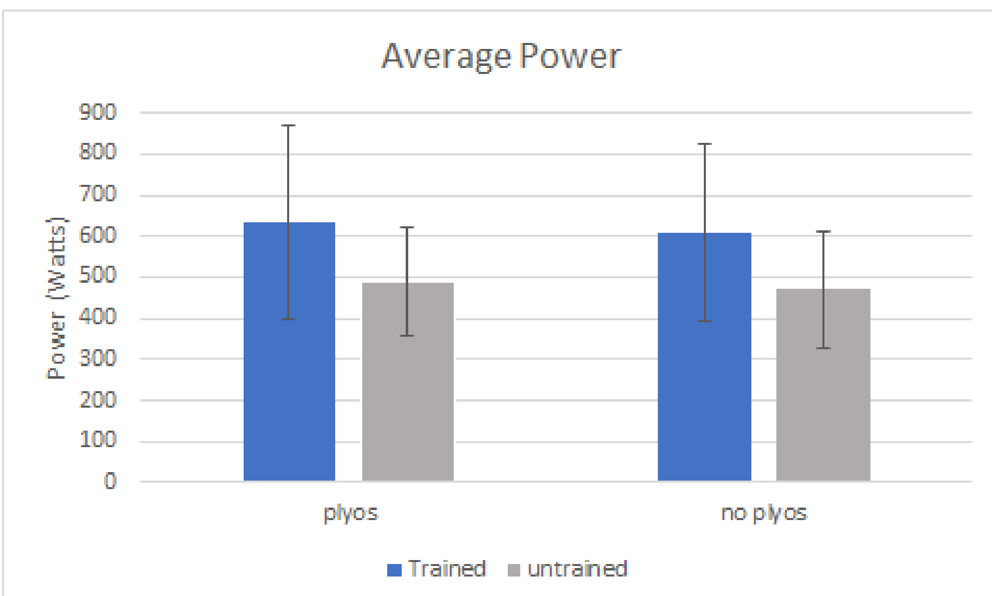

Figure 3. Average Power between different trials and activity levels

Time to Peak. Performing plyometrics did not significantly affect time to peak ($F_{1,9}$ = 3.53, p > 0.05). There were also no significant differences found between different activity levels on time to peak ($F_{1,9}$ = 1.01, p > 0.05), and there were no significant interactions between activity levels and trial types on time to peak (Table 2, $F_{1,9}$ = 0.67, p > 0.05)

Table 2. Descriptive data for Time to Peak

Trial	Activity Level	*Mean* (seconds)	*SD*	*N*
No Plyos	Trained	1.23	0.4	4
	Untrained	0.9	0.57	7
Plyos	Trained	0.83	0.22	4
	Untrained	0.74	0.24	7

Anaerobic Capacity. Performing plyometric drills as a part of the warm-up significantly increased the anaerobic capacity of participants during the WAnT ($F_{1,9}$ = 5.37, p = 0.046), between the trials, plyometrics (7.78 ± 1.513 W/kg) was higher than no plyometrics (7.436 ± 1.507 W/kg). There was also a significant difference found between activity levels ($F_{1,9}$ = 6.44, p = 0.032) for anaerobic capacity. The trained group (8.83 ± 1.54 W/kg) was higher than the untrained **(**7.28 ± 1.03 W/kg). There was no significant interaction between trials and activity level (Fig. 4, $F_{1,9}$ = 5.71, p > 0.05) for anaerobic capacity.

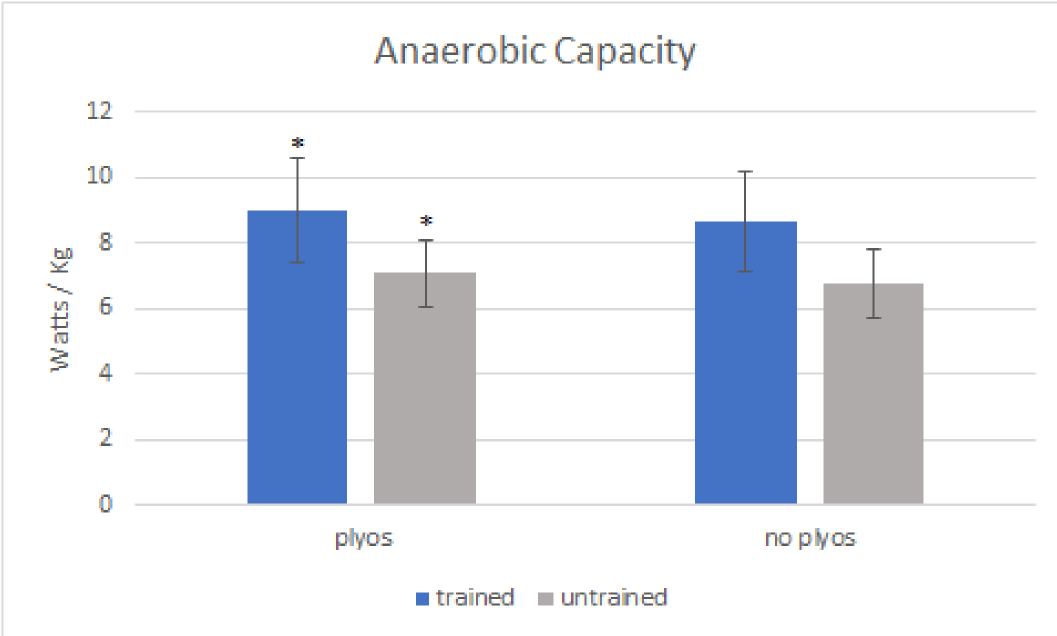

Figure 4. Anaerobic Capacity between different trials and activity levels

Anaerobic Power. Performing plyometric drills as a part of the warm-up significantly increased the anaerobic power of participants during the WAnT ($F_{1,9}$ = 15.77, p = 0.003), between the trials, plyometrics (13.77 ± 1.286 W/kg) was higher than no plyometrics (12.69 ± 1.84 W/kg). There was no significant difference found between activity levels for anaerobic power ($F_{1,9}$ = 0.46, p > 0.05), and there was also no significant interaction found between activity levels and trials ($F_{1,9}$ = 1.53, p > 0.05).

Fatigue Index. Performing plyometrics significantly increased fatigue index of participants ($F_{1,9}$ = 5.41, p = 0.045). Plyometrics (23.65 ± 6.201) was higher than no plyometrics (21.05 ± 6.767) for fatigue index. There were no significant differences found between activity levels ($F_{1,9}$ = 0.36, p > 0.05), nor were there any significant interactions found between activity levels and trials ($F_{1,9}$ = 0.54, p > 0.05) for fatigue index.

RPE. Performing plyometrics did not significantly affect RPE ($F_{1,9}$ = 1.55, p > 0.05). There were also no significant differences between the different activity levels ($F_{1,9}$ = 0.13, p > 0.05), or significant interactions between activity levels and trials ($F_{1,9}$ = 0.24, p > 0.05) for RPE.

Discussion

The current research involved two different populations, one trained and the other untrained, then utilized plyometric drills within those populations to improve power performance. The research suggests that plyometrics had an effect on peak power, anaerobic capacity and anaerobic power. There was also evidence that suggests training status does not have a significant effect on peak power, average power or end power. Performing plyometrics did not significantly affect average power or end power as was hypothesized. The increases in peak power, anaerobic capacity and anaerobic power can be linked directly to the intervention of plyometric drills. Plyometrics utilize the stretch shortening cycle, which uses the series elastic component to store elastic energy (Haff 2016). This can then lead to faster and more forceful contractions. Additionally, plyometrics are dynamic (Lyttle 1996) in design and allow for several neural and physiological adaptations to occur as a result of inducing responses like the stretch-shortening cycle. Rapid eccentric-concentric contractions can also utilize a reflex mechanism that recruits more motor units during the concentric phase of the movement (Chimera 2004).

We were also interested in secondary measurements such as anaerobic capacity and anaerobic power during the WAnT which showed significant differences between the trials. Anaerobic capacity gives an indication to the maximal amount of energy that an individual can produce through the means of anaerobic energy pathways and stores (Scott 1991). A study by Xenofondos et. al. (2010), examined the effects of post-activation potentiation and how power can be increased through a heightened excitability of the central nervous system. This extra excitability is also coupled with a higher phosphorylation following near maximal muscle stimulation, creating an environment that can allow for higher performance from the muscles.

This same reaction may have been induced with the use of plyometric drills in the current study. In a study on female futsal players conducted by Mihri Karavelioglu et al. (2016), it was observed that plyometrics can increase anaerobic capacity. We found that anaerobic capacity was also the only variable that showed a significant difference between the two populations. This may be due to the trained participants being more adapted to the type of stimulus experienced during the study. They have had a longer time to adapt to similar stimuli becoming more efficient at utilizing anaerobic sources of energy. It must be noted that increased rate of force development and motor unit recruitment may require a long period of time to be fully noticed; however, the significance found in the current research may be attributed to acute effects of plyometric drills on anaerobic capacity. Similarly, anaerobic power showed very similar evidence that the plyometric drills had a significant effect between the two trials. In addition to a participant's ability to work anaerobically, fatigue index was measured to observe the rate of performance decline during the WAnT. Fatigue index is a number value associated with a calculated drop-off in performance over a given period of time (Oliver 2007). The results suggest that performing plyometrics prior to the WAnT had subsequent higher fatigue index readings. This can be attributed to the plyometrics improving an individual's ability to perform at higher power outputs. A higher intensity would fatigue the participant at a quicker rate due to the depletion of energy stores and accumulation of anaerobic byproducts.

It must also be noted that our study did not have complete control over the actions of each participant between each session. Each participant was instructed on the importance of limited physical activity between sessions in order to reduce the effects of fatigue on WAnT performance. This uncontrollable variable was a limitation that could be improved on in further research regarding the participant by reducing the amount of time possible between sessions.

Finally, due to the effects of COVID-19, there were limitations to the amount of participants viable for the research. Significant time was spent away from the institution and the student body, which was the main population for recruitment. These limitations may have had an impact on the possible results that could have been attained through a higher participant count.

Conclusion

The plyometrics used in the current research improved the peak power, anaerobic capacity and anaerobic power of participants compared to having no plyometrics within the warm-up. Plyometrics are a viable tool to increase performance, regardless of training status.

Acknowledgements

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Works Cited

1. Biron B. Fitness has exploded into a nearly $100 billion global industry as more people become obsessed with their health [Internet]. Business Insider. Business Insider; 2019.
2. Borg G.A. Psychophysical bases of perceived exertion. *Med Sci Sport Exer*. 1982; 14:377-381.
3. Bredin SS, Gledhill N, Jamnik VK, Warburton DE. PAR-Q+ and ePARmed-X+: new risk stratification and physical activity clearance strategy for physicians and patients alike. *Can Fam Physician*. 2013; 59(3):273-7.
4. Buckner, S.L., Mouser, J.G., Jessee, M.B., Dankel, S.J., Mattocks, K.T. and Loenneke, J.P. What does individual strength say about resistance training status?. *Muscle Nerv* 2017; 55: 455-457.
5. Chimera NJ, Swanik KA, Swanik CB, Straub SJ. Effects of plyometric training on muscle-activation strategies and performance in female athletes. *J. Athl Train*. 2004; 39(1):24-31
6. Chiu LZF, Fry AC, Weiss LW, Schilling BK, Brown LE, Smith SL. Postactivation potentiation response in athletic and recreationally trained individuals. *J Strength Cond Res*. 2003;17(4):671-7.
7. Flanagan EP, Comyns TM. The use of contact time and the reactive strength index to optimize fast stretch-shortening cycle training. *Strength Cond J*. 2008;30(5):32–8.

8. Franco B, Signorelli G, Trajano G, Costa P, de Oliveira C. Acute effects of three different stretching protocols on the Wingate test performance. *J Sport Sci Med*. 2012;11(1):1-7.

9. Gil MH, Neiva HP, Garrido ND, Aidar FJ, Cirilo-Sousa MS, Marques MC, et al. The effect of ballistic exercise as pre-activation for 100 m sprints. *Int J Env Res Pub Health*. 2019;16(10):1850–62

10. Haff G, Triplett NT. *Essentials of Strength Training and Conditioning*. 4th ed. Champaign, IL: Human Kinetics; 2016. Chapter 18, Program design and technique for plyometric Training; p. 472-473.

11. Karavelioglu MB, Harmanci H, Kaya M, Erol M. Effects of plyometric training on anaerobic capacity and motor skills in female futsal players. *Anthropologist*. 2016 Mar 1,;23(3):355-60.

12. Lorenz D. Postactivation potentiation: An introduction. *Int J Spt Phys Th*. 2011;6(3):234-40.

13. Luebbers PE, Potteiger JA, Hulver MW, Thyfault JP, Carper MJ, Lockwood RH. Effects of plyometric training and recovery on vertical jump performance and anaerobic power. *J Strength Cond Res*. 2003;17(4):704–9.

14. Lyttle AD, Wilson GJ, Ostrowski KJ. Enhancing performance: Maximal power versus combined weights and plyometrics training. *J Strength Cond Res*. 1996;10(3):173.

15. Oliver JL. Is a fatigue index a worthwhile measure of repeated sprint ability? *J Sci Med in Sport*. 2007;12(1):20-3.

16. Pearson R, Mounsey B. Ankling. *Runner's World*. London; 2019

17. Rimmer E, Sleivert G. Effects of a plyometrics intervention program on sprint performance. *J Strength Cond Res*. 2000;14(3):295-301.

18. Sarkar, Shikha. Broad Jump. Kit Kat Events and Marketing, 2017

19. Scott CB, Roby FB, Lohman TG, Bunt JC. The maximally accumulated oxygen deficit as an indicator of anaerobic capacity. *Med Sci Sport Exer*. 1991;23(5):618-24.

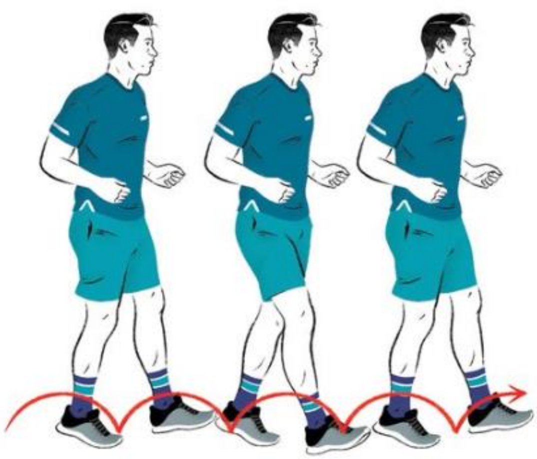
20. Whelan N, Kenny IC, Harrison AJ. An insight into track and field coaches' knowledge and use of sprinting drills to improve performance. *Inter J Sport Sci Coaching*. 2016;11(2):182–90.

21. Xenofondos, A.; Laparidis, K.; Kyranoudis, A.; Galazoulas, C.; Bassa, E.; Kotzamanidis, C. Post-activation potentiation: factors affecting it and the effect on performance. *J Phys Ed Sport.* 2010, 28, 32–39.

22. Zupan M, Arata A, Dawson L, Wile A, Payn T, Hannon M. Wingate anaerobic test peak power and anaerobic capacity classifications for men and women intercollegiate athletes. *J Strength Cond Res*. 2009;23(9):2598-604.

Appendix 1

A-Skips [20]



Ankling [16]

Broad Jump [18]