International Journal of Kinesiology & Sports Science
ISSN: 2202-946X
www.ijkss.aiac.org.au

Acute Effect of Mini-Trampoline Jumping on Vertical Jump and Balance Performance

Nada Rhouni[1], Nicole C. Dabbs[2]*, Trevor Gillum[1], Jared W. Coburn[3]
[1]*California Baptist University, 8432 Magnolia Ave, Riverside, CA 92504*
[2]*California State University, San Bernardino, 5500 University Parkway, San Bernardino, CA 92407*
[3]*California State University, Fullerton, 800 N. State College Blvd., Fullerton, CA 92834-6870*
Corresponding Author: Nicole C. Dabbs, E-mail: ndabbs@csusb.edu

ARTICLE INFO

Article history
Received: January 15, 2019
Accepted: March 10, 2019
Published: April 30, 2019
Volume: 7 Issue: 2

Conflicts of interest: None
Funding: None

ABSTRACT

Background: Jumping and balance are necessary skills for most athletes, and mini-trampoline training has been shown to improve them. Little is known about the acute effect of mini-trampoline jumping on jump performance and dynamic balance. **Objectives:** The purpose of this study is to investigate the effect of 6 maximal jumps on a mini-trampoline on countermovement vertical jump (CMVJ) variables and on balance parameters. **Methods:** Twenty one recreationally trained individuals participated in three testing sessions and were either allocated to a control group (N=10) or a trampoline group (N=11). All the participants performed a dynamic warm up prior to their assessments. Baseline CMVJ and balance assessments were measured. For the jump performance tests, the control group rested for 30s, and the trampoline group performed 6 maximal CMVJs on a mini-trampoline. Immediately following the trampoline jumps or the rest period, participants performed three jump trials. The jumping protocol was repeated every minute up to 5 minutes and balance was reassessed immediately after only. **Results:** There was no significant interaction of time by group and no group effects in all the jumping parameters, however, there was a significant increase in jump height ($p < 0.001$) post-condition, and a significant decrease in peak power ($p = 0.01$) at the 4th minute for both groups. There was no significant interaction of time by condition, no time effect and no group effect ($p > 0.05$) on the balance variables. **Conclusion:** These results do not support our hypothesis and show that trampoline jumping does not improve jump and balance performance acutely.

Key words: Warm-up, Trampoline Exercise, Athletes, Recreationally, Plyometric Exercise

INTRODUCTION

Jumping is a crucial part of many sports, and the improvement of jumping performance has been largely studied. The success of some game-like technical actions in many sports such as basketball, soccer, and volleyball is strongly related to the jumping performance of athletes in terms of height and speed (Ortega, Rodríguez Bíes, & Berral de la Rosa, 2010; Umberger, 1998; Sauls & Dabbs, 2017). The vertical jump test is also used to assess athletes abilities, to distinguish their strengths and weaknesses, and to identify the effectiveness of their trainings (Hara, Shibayama, Takeshita, & Fukashiro, 2006). Plyometric training and repetitive jumping have been shown to be effective to improve vertical jumping in many sports (Bobbert & Van Soest, 1994; Markovic, 2007). However, it involves exercises that lead to high impact forces resulting from landing, which may increase the risk of injury in the lower body (Chu, 1998; Dufek & Bates, 1991; Lyttle, Wilson, & Ostrowski, 1996).

In addition to jumping, balance is also an important skill in many sports. It is defined as the capacity to conserve the body's gravity line with a least deviation on the base of support (Shumway-Cook, Anson, & Haller, 1988). Dynamic balance consist of minimizing the body sway or recovering posture after a disturbance (D. Winter, 1995). The American College of Sport Medicine includes balance training in its "physical activity guidelines" and considers it as a skill-related component of physical fitness ("Advanced Fitness Assessment and Exercise Prescription, Seventh Edition With Online Video," 2014). It is considered as a coordinative characteristic that is necessary for daily simple activities, but also for learning and performing the rapid position change movements that are required by many sports (Atilgan, 2013; Vuillerme et al., 2001), especially those that require complex motor skills like gymnastics (31). The ability to reduce the body sway is an important skill to develop not only by athletes, but also by other populations such as the elderly, as balance has been shown to decrease the risk of falls (Aragão, Karamanidis, Vaz, & Arampatzis, 2011).

According to many studies, mini-trampoline programs not only decrease the trauma of landing (Dufek & Bates, 1991) but are also effective in the improvement of jump height (Atilgan, 2013; Karakollukçu, Aslan, Paoli, Bianco, & Sahin,

Published by Australian International Academic Centre PTY.LTD.

http://dx.doi.org/10.7575/aiac.ijkss.v.7n.2p.1

2015; Ross & Hudson, 1997; Şahin et al., 2016) and balance by stimulating proprioceptors and sensory motor control via adaptation to the trampoline's unstable surface (Hahn, Shin, & Lee, 2015; Heitkamp, Horstmann, Mayer, Weller, & Dickhuth, 2001). Kidgell et. al found that trampoline training significantly affected the postural sway in athletes, resulting in an improvement in balance and stability. This improvement was thought to be due to the enhancement of muscle endurance and the ankles complex muscles' reaction time (Kidgell, Horvath, Jackson, & Seymour, 2007). Heitkam et al. showed that including a mini-trampoline in a balance circuit training led to a better balance performance after only 6 weeks (Heitkamp et al., 2001). Further, a repetitive jumping program on a trampoline caused an improvement of balance due to a reduced forward translation in the jump (Ross & Hudson, 1997), and according to Marquez et.al, many athletes include trampoline in their practice to improve their balance (Márquez et al., 2010).

According to what was mentioned previously, mini- trampoline training may enhance balance and jump performance and can lead to the improvement of athletic performance. However, it is noteworthy that most studies on trampoline jumping focused on the long-term effects of trampoline training, when there has been little research on its effect acutely (Márquez et al., 2010). If trampoline jumping presents immediate benefits in terms of jump performance and balance, it may be an efficient exercise to include for a short-term preparation (e.g. warm-up). According to the principle of specificity, a specific warm up for the vertical jump would be to perform a countermovement vertical jump (CMVJ) (Burkett, Phillips, & Ziuraitis, 2005). Therefore, practicing jumps on a trampoline might present more specificity than other forms of dynamic warm up for sports that require vertical jumping, and may be easily transferred to competitive situations. Among the few studies that investigated the acute influence of landing surfaces on the kinematics of jumping, a study showed reduced joint range of motion during the eccentric phase of the countermovement jump, which results in a reduced loss of elasticity that allows the stretch shortening cycle mechanism to generate a greater maximum leg power during jumping (Crowther, Spinks, Leicht, & Spinks, 2007).

Due to the lack of literature investigating acute mini-trampoline jumping on balance and vertical jump performance, we hypothesize that performing jumps on a trampoline will acutely improve balance variables, including Overall Stability Index (SI), Anterior-posterior Stability Index (API), and Medial-Lateral Stability Index (MLI), and increase the countermovement vertical jump variables, including Jump Height (JH), Peak Force (PF), Peak Velocity (PV), Peak Power (PP), and Rate of Force Development (RFD). Therefore, the purpose of the study is to investigate the immediate effect of trampoline jumping on vertical jump performance and dynamic balance in recreationally trained males and females.

METHODS

Participants and Design

An experimental study design was used to compare a mini-trampoline group to a control group (that did not jump on a trampoline) when assessing CMVJ performance and dynamic balance. The CMVJ performance was used in a repeated measures design to re-assess CMVJ performance at baseline, immediately post intervention, and every minute up to 5 minutes. Dynamic balance used a mix-factor analysis to compare pre and post intervention between groups.

Twenty-one recreationally trained individuals (males= 14 and females= 7, age: 23 ± 2, height: 170.7 ± 9.3 cm, body mass: 70.1 ± 11.1 kg) volunteered to participate in three lab sessions separated by at least 24 hours. One participant did not attend the balance condition, resulting in a sample size of 20 for the balance measures. The participants were recruited from a university via classroom recruitment, campus advertisement via flyers, and verbal recruitment. Recreationally trained subjects were defined as individuals who have been participating in endurance or resistance training, or a combination of both, three times per week for at least the last six months. Individuals reporting any lower body musculoskeletal injury within the last six months were excluded from the experiment. All participants were asked to refrain from any physical activity at least 24 hours prior to their visits and were instructed to wear comfortable clothes and athletic shoes. Prior to their participation to the research study, all participants were required to read and sign an informed consent approved by the university Institutional Review Board (IRB).

Experimental Procedures

First visit

During the first visit, the participants read and signed the IRB approved informed consent document and completed the Physical Activity Readiness Questionnaire (PAR-Q) and health history questionnaire. After verifying they did not present the exclusionary criteria, their anthropometrics (age, height, weight) were measured. Subjects then performed a dynamic warm-up that included: 2 sets of 15 meters of jogs, high knees, exaggerated lunges, walking Frankensteins, and leg swings for 30s on (both sides, and forward-backward). Following that, they were familiarized with the testing procedures and equipment, which includes jumping on the ground and on the mini-trampoline, using the Vertec® (floor model) and balance assessment using the Biodex Balance System SD (Balance System ™ SD, Shirley, NY, USA).

Second visit

During the second visit, the participants completed a 24-hour history questionnaire to confirm that they did not exercise 24 hours prior to the test session and that they maintained a normal diet and normal sleep. Participants were randomly allocated to either a control group (CG) or a trampoline group (TG) before continuing.

Participants performed three maximal CMVJ on an AMTI force plate (Advanced Mechanical Technology, Inc., Watertown, BP 600900-1000) with 15s rest between each jump. PP, PV, PF and RFD were recorded and calculated by a customized LabView instruments code for all jumps. Participant's vertical jump height was measured using the Vertec Vertical Jump Tester (sports imports), that was considered a visual target by the participants. The difference between the fully extended standing reach height and the maximal vertical jump was calculated for analysis. The standing reach height was measured by having each subject stand in front of the Vertec jumping device, walk while keeping the heels on the floor, and reach upward to move the device's vanes. To perform the CMVJ, the subjects were instructed to stand with the feet apart, bend at the knees and hips quickly, and jump vertically and explosively as high as possible with an arm swing.

Following baseline measurements, the CG rested for 30s, and the TG performed 6 maximal CMVJs on a mini-trampoline (Sport Plus Fitness Trampoline, diameter 110 cm, jumping pad surface diameter: 84 cm), and were instructed to jump as high as possible during the time period. Immediately following the trampoline jumps or the rest period, participants performed three jump trials with 15s rest between the jumps. The jumping protocol was repeated every minute up to 5 minutes. Post measurements and CMVJ measures were reassessed, including JH, PP, PV, PF, and RFD. The maximum values of the three jump heights obtained were used for the data analysis. All the CMVJ were performed on a force plate sampled at a rate of 1600 Hz. The force plate was zeroed prior to having participants perform the CMVJs on it. Consequently, the force values measured include body mass.

Third visit

During the third visit, the participants completed a 24-hour history questionnaire to confirm that they did not exercise 24 hours prior to the test session and that they maintained a normal diet and normal sleep hours. Participants performed a dynamic warm up followed by a baseline balance assessment. Participants were then randomly allocated to either a CG or a TG. The CG rested for 30s, and their balance was re-assessed. The TG performed 6 maximal jumps on a trampoline and their balance was re-assessed immediately after. The Biodex Balance System SD (950-440) was used to assess the participants double leg (DL) sway during unstable conditions (level 4) without shoes by tracking the displacement of the center of pressure for 20 seconds, three times, with 10 seconds of rest in between. The Overall Stability Index (SI), Anterior-Posterior Stability Index (API) and Medial Lateral Stability Index (MLI) were recorded for analysis.

Formulas

SI represents the variance of foot platform displacement in degrees, during the whole test duration.

$$\mathrm{SI} = \sqrt{\frac{\sum (0-X)^2 + \sum (0-Y)^2}{3}}$$

API represents the variance of foot platform displacement in degrees in the sagittal plane:

$$\mathrm{API} = \sqrt{\frac{\sum (0-Y)^2}{3}}$$

MLI represents the variance of foot platform displacement in degrees in the frontal plane.

$$\mathrm{MLI} = \sqrt{\frac{\sum (0-X)^2}{3}}$$

Statistical Analysis

All statistical analysis was performed through the use of a statistical package for social sciences-24 (SPSS-24). An Alpha level of 0.05 was used to determine statistical significance in all comparisons. A 2x7 (group x time) mix-factorial analysis of variance (ANOVA) was used to determine the differences across the time and groups for each jumping variable, which include JH, PP, PV, PF, and RFD. A least significant difference (LSD) post hoc analysis was performed to determine time effects, if needed. A 2x2 (time x condition) mix-factorial ANOVA was used to determine the differences between pre and post conditions and between groups for each balance variable, which include SI, API, and MLI.

RESULTS

CMVP Performance

There was no significant interaction of time by group ($p > 0.05$), and no group effect for all the variables JH, PF, PV, PP, RFD. Also, there was no significant time effect in PF, PV and RFD.

However, there was a significant increase in JH ($p < 0.001$) for all the time points post-condition compared to baseline values, and a significant decrease in PP ($p = 0.018$, $p < 0.05$) at the 4th minute for both groups (Figure 1). The data for all jumping variables was represented as mean ± SD in Table 1.

Balance Performance

There was no significant interaction of time by condition ($p > 0.05$) for the variables Overall Stability Index ($p = 0.28$, Anterior-Posterior Stability Index ($p = 0.62$) and Medial Lateral Stability Index ($p = 0.09$). There was no significant time effect ($p > 0.05$) for Overall Stability Index ($p = 0.79$), Anterior-Posterior Stability Index ($p = 0.76$) and Medial Lateral Stability Index ($p = 0.94$). Also, there was no significant group effect ($p > 0.05$) for Overall Stability Index ($p = 0.55$), Anterior-Posterior Stability Index ($p = 0.44$) and Medial Lateral Stability Index ($p = 0.44$). These results do not support out hypothesis. A high balance score indicates that there was high movement during the balance test. Results are shown in Table 2.

SI = Overall Stability Index; API = Anterior-Posterior Stability Index; MLI = Medial Lateral Stability Index. Trampoline group (N=10); Control group (N=10).

DISCUSSION

CMVJ Performance

It was hypothesized that trampoline jumping would have a significant effect on JH, PF, PV, PP, and RFD, however, there

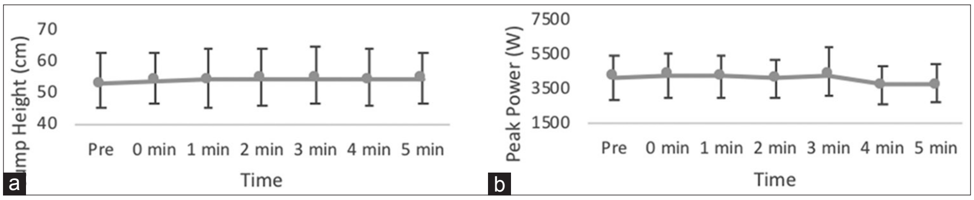

Figure 1. Jump performance variables (mean ± SD) (a) Jump Height (JH) (b) and Peak Power (PP) in both groups (N=21) and across all time points. There was a significant increase in JH for both groups immediately after jumping and a significant decrease in PP in the 4th minute

Table 1. Countermovement Vertical Jump Data

Variable	Group	Pre (baseline)	0 min	1 min	2 min	3 min	4 min	5 min
JH (cm)	Control	52±8	53±7*	53±9*	54±8*	54±8*	54±8*	54±8*
	Trampoline	53±11	54±10*	55±11*	55±11*	55±11*	54±11*	55±8*
	Total	53±9	54±9*	54±9*	54±9*	54±10*	54±10*	54±9*
PF (N)	Control	1707±364	1692±337	1677±345	1706±348	1692±370	1648±343	1676±355
	Trampoline	1555±339	1638±35	1612±326	1596±295	1645±323	1559±330	1625±272
	Total	1635±353	1666±337	1646±330	1653±321	1670±341	1605±331	1651±312
PV (m/s)	Control	2.95±0.37	3.04±0.27	2.95±0.33	2.96±0.37	2.90±0.29	2.79±0.35	2.91±0.23
	Trampoline	2.93±0.44	2.98±0.39	3.01±0.42	2.84±0.40	3.09±0.81	2.76±0.44	2.62±0.23
	Total	2.94±0.40	3.01±0.33	2.98±0.37	2.91±0.38	3.00±0.59	2.78±0.39	2.78±0.61
PP (W)	Control	4290±1253	4423±1311	4250±1170	4325±1170	4182±1223	3863±1129*	4063±1004
	Trampoline	3930±1331	4057±1212	4075±1363	3766±1105	4293±1899	3555±1089*	3360±1253
	Total	4119±1271	4249±1247	4167±1236	4059±1182	4235±1541	3716±1094*	3728±1158
RFD (N/s)	Control	2744±1900	2945±1325	3460±1833	3363±1681	3530±1669	3254±1745	3608±2011
	Trampoline	2628±1427	3705±1564	3083±1453	3005±1757	3355±1827	3455±1573	2984±1679
	Total	2689±1651	3307±1460	3280±1633	3193±1684	3447±1704	3350±1627	3310±1842

Variables of countermovement vertical jumps (CMVJ) between groups (Trampoline group (N=11), control group (N=10)) and across all time points. The mean±SD of Jump Height (JH), Peak Force (PF), Peak Velocity (PV), Peak Power (PP), and Rate of Force Development (RFD) for each condition and for each group. *significant difference from baseline at $p<0.05$

Table 2. The mean±SD of SI, API, and MLI for each condition and for each group.

	Pre-condition SI	Post- condition SI	Pre-condition API	Post- condition API	Pre-condition MLI	Post- condition MLI
Trampoline group	0.72±0.26	0.76±32	0.52±0.19	0.49±0.30	0.38±0.12	0.43±0.14
Control group	0.86±0.39	0.795±40	0.59±0.25	0.59±0.31	0.49±0.27	0.44±0.18

SI=Overall Stability Index; API=Anterior-Posterior Stability Index; MLI=Medial Lateral Stability Index. Trampoline group (N=10); Control group (N=10).

were no significant difference in the CMVJ variables between the control and the trampoline groups. There was a significant time effect on JH and PP, as JH increased significantly immediately post-condition for both groups, and PP decreased significantly on the 4th minute for both groups ($p<0.05$).

Jumping ability is a crucial skill that affects performance in many sports (Crowther et al., 2007). Improving vertical jump performance has been investigated by many scientists and coaches and is still of great interest for researchers, as improving vertical jump performance with a reduced risk of injury is one of the most sought-after objectives for athletes (Tran, Brown, Coburn, Lynn, & Dabbs, 2012). Vertical jump has also been used by coaches and practitioners to assess athletes maximal force and power output (Arteaga, Dorado, Chavarren, & Calbet, 2000; Hara et al., 2006). Plyometric exercises that include many jumping variations improve the stretch-shortening cycle (SSC) phenomenon and have been shown to improve jumping height and velocity (Crowther et al., 2007; Markovic, 2007; Ross & Hudson, 1997), however, repetitive vertical ground reaction forces generated from landing can lead to injury (Crowther et al., 2007; Dufek & Bates, 1991; Ortega et al., 2010). Those forces may be 2.5 times higher than those found in running conditions (Cavanagh & Lafortune, 1980). Researchers have investigated methods to decrease those high landing forces, and the use of mini-trampolines has been shown to be an efficient way to reduce landing forces caused by jumping (Dufek & Bates, 1991).

It has been demonstrated that mini-trampoline training is an effective exercise to improve jump performance (Atilgan, 2013; Ross & Hudson, 1997; Şahin et al., 2016). In addition to improving lower body strength and endurance, mini-trampoline training also improves balance (Aragão et al., 2011; Atilgan, 2013; de Oliveira, da Silva, Dascal, & Teixeira, 2014), which has been suggested to improve vertical jump height due to a reduced postural sway that allows the orientation of propulsive forces in a more vertical direction (Chaouachi, Othman, Hammami, Drinkwater, & Behm, 2014).

The current investigation shows an improvement of jump height immediately after the trampoline jumps and the rest period that is sustained for 5 minutes post jumping for both groups, however, the time and group interaction for jump height was not significant, which suggests that performing 6 maximal jumps on a trampoline does not cause a significant improvement in jump height compared to not jumping at all for 30s. The improvement achieved by both groups might be due to a learning effect. These results contradict the conclusions of a study by Márquez et al. (Márquez et al., 2010) that showed that 1-min of jumping on a trampoline increases leg stiffness and decreased jump height. This might be due to the difference in the number of jumps performed, as in the previous study, the participants jumped on a trampoline for 60 seconds, which may have led to fatigue.

A individual performing a CMVJ has to produces high forces to overcome body weight and the ground reaction forces (Linthorne, 2001), but no immediate significant improvement was obtained in terms of maximal force in this study. Maximum force was found to be significantly dependent on height jumped in a previous study (Dowling & Vamos, 1993), which might explain why no significant time and group interactions was found in terms of peak force during CMVJ in our study.

Although peak force and peak velocity did not have a significant effect on jump parameters, peak power significantly decreased on the 4th minute ($p = 0.01$). This might be caused by fatigue, as participants performed many jumps during the test session. Peak power represents the product of force and velocity (Turner, Unholz, Potts, & Coleman, 2012), and was suggested to be the best predictor of jump height values, and to indicate the efficiency of energy transfer between the jumper's body segments while performing a CMVJ (Dowling & Vamos, 1993). The current investigation shows that performing 6 maximal jumps on a mini-trampoline showed no significant time by group interactions on peak power, which might explain why we obtained similar results in terms of jump height.

The rate of force development is the rate of increase in contractile forces during muscle contractions (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002) and the RFD produced by the muscles of the lower body are thought to be a measure of explosive strength and to contribute to CMVJ performance (McLellan, Lovell, & Gass, 2011; D. A. Winter, 2009). In this study, no significant group, time, and time by group interaction was found for RFD, which suggests that this parameter does not improve acutely.

Balance Performance

In this study, the results of the dynamic balance performance test show that performing 6 maximal jumps on a trampoline do not have a significant immediate effect on balance parameters, which does not support our hypothesis. Atilgan (2013), has found in his study that 12 weeks of trampoline training has led to the improvement of bipedal stability, and suggested that it might be due to coordination between both legs that is required when the trampoline is used (Atilgan, 2013). His study suggests that jumping on a trampoline requires to control the body position in the air at every jump, to use an adequate landing technique to avoid falling, and to constantly adapt the eyes to successive images, which requires a constant reorientation that enhances coordination and balance (Atilgan, 2013). Another study compared the effect of 12 weeks of aerobic training on a trampoline to an aerobic training on a had wooden surface, and showed that the training increased muscular strength and balance: to stay balanced, the mini-trampoline group required a higher motor unit recruitment to conserve their position on the unstable surface (Sukkeaw, Kritpet, & Bunyaratavej, 2015), which eventually caused muscle development and growth.

In conclusion, this study shows that there is no significant acute effect on jump performance and balance when 6 maximal jumps are performed on a trampoline compared to 30 seconds of rest. Most of the studies that have reported an improvement in jump performance and balance involved a long duration training (12 to 14 weeks). This might be due to the long-term adaptation of the body to trampoline training. Research has shown that muscular endurance in the muscles around the ankle is an important factor that improves balance ability, which might be developed by training for a long duration on a trampoline (Kaminski et al., 2003). Jumping on an unstable surface stimulates muscular strength in the lower body (Aragão et al., 2011; de Oliveira et al., 2014), which implies that any improvement in CMVJ performance or balance requires time for the lower body muscles to achieve a certain level of strength and endurance to adapt.

To our knowledge, this is the first study to examine the acute effect of 6 maximal jumps on a trampoline on CMVJ performance and balance, which was found to not be significant between the control group and the trampoline group. However, this study has some limitations. It is possible that no significant effect was found because of the number of trampoline jumps that might have been too low to obtain an effect, nonetheless, the number of jumps was chosen to limit fatigue and produce a maximal power during the jumps. Additionally, the participants who participated in this study were all recreationally trained, but were not equally trained in explosive exercise, endurance, balance, and flexibility, and did not have a similar experience in jump performance. CMVJ and balance performance depends on the interaction of many factors including muscular strength, endurance and power in the lower body and core (Hopkins, 2000; Hopkins, Schabort, & Hawley, 2001), which might have affected the results in this study, those measures were not evaluated. In addition to that, psychological parameters were not evaluated but is possible that individual psychological motivation could also have influenced their jump and balance performance. However, this outcome was not assessed nor controlled in the present study since all subjects were similarly motivated to participate in the study.

Consequently, we suggest that further studies should be conducted using a higher number of jumps to give more specific recommendations to trainers and coaches regarding the addition of jumps to the warm up or training program. Also, the present work has only compared the trampoline group to a control group that did not jump. More research is needed to compare the immediate CMVJ and balance performance parameters of subjects jumping on a trampoline to subjects jumping on a hard surface.

CONCLUSION

Warming up before any physical activity is proven to improve performance and to lower the risk of injury (Safran, Garrett, Seaber, Glisson, & Ribbeck, 1988) by increasing neural activation and range of motion (McArdle, Katch, & Katch, 2010; McNair & Stanley, 1996; Safran et al., 1988; Wiemann & Hahn, 1997). Practice trials of an exercise were suggested to be efficient at improving the performance of this skill (Young & Behm, 2003), as it presents more specificity. It is believed that it "opens up specific neural pathways to facilitate motor unit activation" (Young & Behm, 2003). This study did not show a significant immediate effect of jumping on a mini-trampoline on jump and balance performance, which also shows that it does not impair any of the parameters that effect jump and balance performance. Consequently, trampoline jumping might be substituted for vertical jumps on a hard surface in a warm up, thus decreasing the forces applied to the joints related to jumping and the risk of injury related to that.

REFERENCES

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology*, *93*(4), 1318–1326. https://doi.org/10.1152/japplphysiol.00283.2002

Advanced Fitness Assessment and Exercise Prescription, Seventh Edition With Online Video: Recommended balance training programs for older adults. (2014, October 19). Retrieved December 7, 2017, from http://www.humankinetics.com/excerpts/excerpts/recommended-balance-training-programs-for-older-adults

Aragão, F. A., Karamanidis, K., Vaz, M. A., & Arampatzis, A. (2011). Mini-trampoline exercise related to mechanisms of dynamic stability improves the ability to regain balance in elderly. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology*, *21*(3), 512–518. https://doi.org/10.1016/j.jelekin.2011.01.003

Arteaga, R., Dorado, C., Chavarren, J., & Calbet, J. A. (2000). Reliability of jumping performance in active men and women under different stretch loading conditions. *The Journal of Sports Medicine and Physical Fitness*, *40*(1), 26–34.

Atilgan, O. E. (2013). Effects of trampoline training on jump, leg strength, static and dynamic balance of boys. *Science of Gymnastics Journal*, *5*, 15–25.

Bobbert, M. F., & Van Soest, A. J. (1994). Effects of muscle strengthening on vertical jump height: a simulation study. *Medicine and Science in Sports and Exercise*, *26*(8), 1012–1020.

Burkett, L. N., Phillips, W. T., & Ziuraitis, J. (2005). The best warm-up for the vertical jump in college-age athletic men. *Journal of Strength and Conditioning Research*, *19*(3), 673–676. https://doi.org/10.1519/15204.1

Cavanagh, P. R., & Lafortune, M. A. (1980). Ground reaction forces in distance running. *Journal of Biomechanics*, *13*(5), 397–406.

Chaouachi, A., Othman, A. B., Hammami, R., Drinkwater, E. J., & Behm, D. G. (2014). The combination of plyometric and balance training improves sprint and shuttle run performances more often than plyometric-only training with children. *Journal of Strength and Conditioning Research*, *28*(2), 401–412. https://doi.org/10.1519/JSC.0b013e3182987059

Chu, D. A. (1998). *Jumping Into Plyometrics*. Human Kinetics.

Crowther, R. G., Spinks, W. L., Leicht, A. S., & Spinks, C. D. (2007). Kinematic responses to plyometric exercises conducted on compliant and noncompliant surfaces. *Journal of Strength and Conditioning Research*, *21*(2), 460–465. https://doi.org/10.1519/R-19645.1

de Oliveira, M. R., da Silva, R. A., Dascal, J. B., & Teixeira, D. C. (2014). Effect of different types of exercise on postural balance in elderly women: a randomized controlled trial. *Archives of Gerontology and Geriatrics*, *59*(3), 506–514. https://doi.org/10.1016/j.archger.2014.08.009

Dowling, J. J., & Vamos, L. (1993). Identification of Kinetic and Temporal Factors Related to Vertical Jump Performance. *Journal of Applied Biomechanics*, *9*(2), 95–110. https://doi.org/10.1123/jab.9.2.95

Dufek, J. S., & Bates, B. T. (1991). Biomechanical Factors Associated with Injury During Landing in Jump Sports. *Sports Medicine*, *12*(5), 326–337. https://doi.org/10.2165/00007256-199112050-00005

Hahn, J., Shin, S., & Lee, W. (2015). The effect of modified trampoline training on balance, gait, and falls efficacy of stroke patients. *Journal of Physical Therapy Science*, *27*(11), 3351–3354. https://doi.org/10.1589/jpts.27.3351

Hara, M., Shibayama, A., Takeshita, D., & Fukashiro, S. (2006). The effect of arm swing on lower extremities in vertical jumping. *Journal of Biomechanics*, *39*(13), 2503–2511. https://doi.org/10.1016/j.jbiomech.2005.07.030

Heitkamp, H.-C., Horstmann, T., Mayer, F., Weller, J., & Dickhuth, H.-H. (2001). Gain in Strength and Muscular Balance After Balance Training. *International Journal of Sports Medicine*, *22*(04), 285–290. https://doi.org/10.1055/s-2001-13819

Hopkins, W. G. (2000). Measures of Reliability in Sports Medicine and Science. *Sports Medicine*, *30*(1), 1–15. https://doi.org/10.2165/00007256-200030010-00001

Hopkins, W. G., Schabort, E. J., & Hawley, J. A. (2001). Reliability of Power in Physical Performance Tests. *Sports Medicine*, *31*(3), 211–234. https://doi.org/10.2165/00007256-200131030-00005

Kaminski, T., Buckley, B., Powers, M., Hubbard, T., Ortiz, C., & Mattacola, C. (2003). Effect of strength and proprioception training on eversion to inversion strength ratios in subjects with unilateral functional ankle instability. *British Journal of Sports Medicine*, *37*(5), 410–415. https://doi.org/10.1136/bjsm.37.5.410

Karakollukçu, M., Aslan, C. S., Paoli, A., Bianco, A., & Sahin, F. N. (2015). Effects of mini trampoline exercise on male gymnasts' physiological parameters: a pilot study. *The Journal of Sports Medicine and Physical Fitness*, *55*(7–8), 730–734.

Kidgell, D. J., Horvath, D. M., Jackson, B. M., & Seymour, P. J. (2007). Effect Of Six Weeks Of Dura Disc And Mini-Trampoline Balance Training On Postural Sway In Athletes With Functional Ankle Instability. *The Journal of Strength & Conditioning Research*, *21*(2), 466.

Linthorne, N. P. (2001). Analysis of standing vertical jumps using a force platform. *American Journal of Physics*, *69*(11), 1198–1204. https://doi.org/10.1119/1.1397460

Lyttle, A. D., Wilson, G. J., & Ostrowski, K. J. (1996). Enhancing Performance: Maximal Power Versus Combined Weights and Plyometrics Training. *Journal of Strength and Conditioning Research*, *10*(3), 173–179.

Markovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British Journal of Sports Medicine*, *41*(6), 349–355. https://doi.org/10.1136/bjsm.2007.035113

Márquez, G., Aguado, X., Alegre, L. M., Lago, Á., Acero, R. M., & Fernández-del-Olmo, M. (2010). The trampoline aftereffect: the motor and sensory modulations associated with jumping on an elastic surface. *Experimental Brain Research*, *204*(4), 575–584. https://doi.org/10.1007/s00221-010-2324-1

McArdle, W. D., Katch, F. I., & Katch, V. L. (2010). *Exercise Physiology: Nutrition, Energy, and Human Performance*. Lippincott Williams & Wilkins.

McLellan, C. P., Lovell, D. I., & Gass, G. C. (2011). The role of rate of force development on vertical jump performance. *Journal of Strength and Conditioning Research*, *25*(2), 379–385. https://doi.org/10.1519/JSC.0b013e3181be305c

McNair, P. J., & Stanley, S. N. (1996). Effect of passive stretching and jogging on the series elastic muscle stiffness and range of motion of the ankle joint. *British Journal of Sports Medicine*, *30*(4), 313–317. https://doi.org/10.1136/bjsm.30.4.313

Ortega, D. R., Rodríguez Bíes, E. C., & Berral de la Rosa, F. J. (2010). Analysis of the vertical ground reaction forces and temporal factors in the landing phase of a countermovement jump. *Journal of Sports Science & Medicine*, *9*(2), 282–287.

Ross, A., & Hudson, J. (1997). Efficacy of a Mini-Trampoline Program for Increasing the Vertical Jump. *ISBS - Conference Proceedings Archive*, *1*(1). Retrieved from https://ojs.ub.uni-konstanz.de/cpa/article/view/3715

Safran, M. R., Garrett, W. E., Seaber, A. V., Glisson, R. R., & Ribbeck, B. M. (1988). The role of warmup in muscular injury prevention. *The American Journal of Sports Medicine*, *16*(2), 123–129. https://doi.org/10.1177/036354658801600206

Şahin, G., Demir, E., Aydın, H., Şahin, G., Demir, E., & Aydın, H. (2016). Does Mini-Trampoline Training More Effective than Running on Body Weight, Body Fat, VO2 max and Vertical Jump in Young Men? *International Journal of Sports Science*, *6*(1), 1–5.

Sauls, N.M. & Dabbs, N.C. (2017). Difference In Male Collegiate and Recreationally Trained Soccer Players on Balance, Agility, and Vertical Jump Performance. *International Journal of Kinesiology & Sports Science*, 5(4), 45-50.

Shumway-Cook, A., Anson, D., & Haller, S. (1988). Postural sway biofeedback: its effect on reestablishing stance stability in hemiplegic patients. *Archives of Physical Medicine and Rehabilitation*, *69*(6), 395–400.

Sukkeaw, W., Kritpet, T., & Bunyaratavej, N. (2015). A Comparison between the Effects of Aerobic Dance Training on Mini-Trampoline and Hard Wooden Surface on Bone Resorption, Health-Related Physical Fitness, Balance, and Foot Plantar Pressure in Thai Working Women. *Journal of the Medical Association of Thailand = Chotmaihet Thangphaet*, *98 Suppl 8*, S58-64.

Tran, T. T., Brown, L. E., Coburn, J. W., Lynn, S. K., & Dabbs, N. C. (2012). Effects of assisted jumping on vertical jump parameters. *Current Sports Medicine Reports*, *11*(3), 155–159. https://doi.org/10.1249/JSR.0b013e31825640bb

Turner, A. P., Unholz, C. N., Potts, N., & Coleman, S. G. S. (2012). Peak power, force, and velocity during jump squats in professional rugby players. *Journal of Strength and Conditioning Research*, *26*(6), 1594–1600. https://doi.org/10.1519/JSC.0b013e318234ebe5

Umberger, B. R. (1998). Mechanics of the Vertical Jump and Two-Joint Muscles: Implications for Training. *Strength & Conditioning Journal*, *20*(5), 70.

Vuillerme, N., Danion, F., Marin, L., Boyadjian, A., Prieur, J. M., Weise, I., & Nougier, V. (2001). The effect of expertise in gymnastics on postural control. *Neuroscience Letters*, *303*(2), 83–86. https://doi.org/10.1016/S0304-3940(01)01722-0

Wiemann, K., & Hahn, K. (1997). Influences of Strength, Stretching and Circulatory Exercises on Flexibility Parameters of the Human Hamstrings. *International Journal of Sports Medicine*, *18*(05), 340–346. https://doi.org/10.1055/s-2007-972643

Winter, D. (1995). Human balance and posture control during standing and walking. *Gait & Posture*, *3*(4), 193–214. https://doi.org/10.1016/0966-6362(96)82849-9

Winter, D. A. (2009). *Biomechanics and Motor Control of Human Movement*. John Wiley & Sons.

Young, W. B., & Behm, D. G. (2003). Effects of running, static stretching and practice jumps on explosive force production and jumping performance. *The Journal of Sports Medicine and Physical Fitness*, *43*(1), 21–27.