Maximum Vertical Jump Height Improves after Two Miles of Running

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Maximum vertical jump height may be affected by the type of warm-up performed. In this study, we investigated how a two-mile run affected vertical jump height. The working hypothesis was that a two-mile run would lead to increased jump height after the run. Twenty-two female subjects (19.8 ± 1.2 years) gave written consent to participate. After measuring height, weight, and standing reach, subjects rested for fifteen minutes. Subjects then performed five maximum vertical jumps, ran two miles on a treadmill at a self-selected pace, and then performed a second set of five maximum vertical jumps. Rating of perceived exertion (RPE) and affect were administered at three time points: after the first set of jumps, after the run, and after the second set of jumps. An electrogoniometer was used to standardize knee joint angle for jumps within a set. Subjects' jump height significantly increased ($p=0.019$) from pre- to post-exercise. Subjects' RPE scores were no different after the two sets of jumps, but were significantly higher after the run compared to either jump set (both $p \leq 0.002$); tandemly, subjects' affect scores were no different after the two sets of jumps, but were significantly lower after the run compared to either jump set (both $p \leq 0.045$). Run time did not correlate with jump height. These findings show that a two-mile run can increase vertical jump height, suggesting a possible benefit of running prior to activities requiring vertical jumping.

Introduction

Warm-ups are an integral part of athletic performance; when implemented correctly, they may reduce the risk of injury and improve athletic performance. Athletes have many options for warm-up protocols, each with differing effects on athletic performance and each specific to desired athletic outcomes (Bradley, Olsen, & Portas, 2007; Daneshjoo, Mokhtar, Rahnama, & Yusof, 2012; Jaggers, Swank, Frost, & Lee, 2008). The purpose of this study was to compare the acute effects of different modes of stretching on vertical jump performance. Eighteen male university students (age, 24.3 +/- 3.2 years; height, 181.5 +/- 11.4 cm; body mass, 78.1 +/- 6.4 kg; mean +/- SD. Vertical jumping is an important performance component of many sports including volleyball, basketball, and gymnastics, and may also be used as a test for general power (Klavora, 2000). Given that a few centimeters' difference in jump height can make a significant impact on jump performance, athletes often seek to improve their vertical jump height (Vetter, 2007; Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004)with and without stretches, on 2 different power maneuvers: a 30-m sprint run and a vertical countermovement jump (CJ and many investigators have focused on different warm-up protocols that may influence vertical jump height.

Much research has focused on how vertical jump height may be influenced by stretching, which comes in many forms including static, ballistic, dynamic, and proprioceptive neuromuscular facilitation (PNF). Static stretching is when a muscle is stretched to mild discomfort and held for a period of time. Most original research studies have concluded that static stretching is generally associated with negative performance outcomes (Bradley et al., 2007; Carvalho et al., 2012; Damasceno et al., 2014; Holt & Lambourne, 2008; Sim, Dawson, Guelfi, Wallman, & Young, 2009; Simic, Sarabon, & Markovic, 2013). *Ballistic stretching* involves moving the muscles in constant bouncing motions. While some studies found a positive effect of ballistic stretching on vertical jump performance (Kirmizigil, Ozcaldiran, & Colakoglu, 2014; Konrad & Tilp, 2014; Woolstenhulme, Griffiths, Woolstenhulme, & Parcell, 2006), others reported no benefit (Bradley et al., 2007; Jaggers et al., 2008; Unick, Kieffer, Cheesman, & Feeney, 2005). *Dynamic stretching* engages athletes in motions similar to sport-specific actions, but at lower speeds and intensities. Most studies have found dynamic stretching improves jump height, power, and flexibility (Aguilar et al., 2012; Behm & Chaouachi, 2011; Faigenbaum, Bellucci, Bernieri, Bakker, & Hoorens, 2005; Jaggers et al., 2008), while others have found no overall benefit or detriment (Carvalho et al., 2012). Including weights with dynamic stretching may also improve jump height (Burkett, Phillips, & Ziuraitis, 2005). *Proprioceptive neuromuscular facilitation* (PNF) is the alternation of contractions and stretches in targeted muscles or muscle groups. While PNF is reported to improve flexibility, it hinders or has no effect on jump performance (Bradley et al., 2007; Dallas et al., 2014; Marek et al., 2005; Place, Blum, Armand, Maffiuletti, & Behm, 2013; Sady, Wortman, & Blanke, 1982).

Less is known about non-stretching warm-up protocols which may also influence jump performance, such as running. One study found that four minutes of submaximal running improved concentric[1] and drop jumping performance[2] compared to static stretching (Young & Behm, 2003). Another study found that

1 Concentric jump: a jump performed from a squat position.

2 Drop jump: beginning on top of a box, the subject steps off and jumps immediately after hitting the ground.

two warm-up protocols (walk-run and walk-run with dynamic stretching) resulted in higher vertical jumps as compared to static stretching (Vetter, 2007).

Based on the current body of research, it is presently unknown if longer duration running would have similar or differing effects on vertical jump performance. It is also unclear how warm-up running might affect athletes' perception of their vertical jump performance, such as their rating of perceived exertion (RPE) or general feelings. Since these ideas have not been deeply explored, the purpose of this study was to examine if a 2-mile run affects the maximum vertical jump heights of active female subjects. Our hypotheses were that a 2-mile run would (a) increase maximum vertical jump and be associated with (b) larger RPE and feeling scores.

Materials and Methods

Approval to conduct human subjects research was received from the Drake University Institutional Review Board (#2012-13013) prior to starting the experiment. Inclusion criteria included being an endurance-trained female able to run two miles in twenty minutes or less. Initially, we aimed to recruit female volleyball players only, as this population would benefit directly from this research; however, we could not recruit enough female volleyball players (either collegiate or intramural) to participate, so we adjusted our recruitment strategy to include females from endurance-trained athletes to recreational runners. Exclusion criteria included if subjects presented with any injuries or biomechanical abnormalities that precluded their safety to participate or ability to complete the exercise. Twenty-two female subjects gave written informed consent to participate (19.8 ± 1.2 years, 171.0 ± 6.5 cm height, 62.2 ± 8.1 kg mass).

Upon arrival in the lab, participants' height, weight, and standing reach were taken. The standing reach[3] for each individual subject was subtracted from their jump heights before data entry. Subjects were then given a fifteen-minute sitting rest period in order to standardize their physical and mental states. Following the rest period, an electrogoniometer[4] (Vernier Software and Technology LLC) was attached to the subject's left knee. Subjects were asked to perform five maximum vertical jumps. Jump height was determined by a Vertec Vertical Jump Testing Apparatus[5] (Jump USA). The electrogoniometer allowed real-time knee angle measurements to be taken during the stance of each jump so that pre-jump knee angles could be standardized to ± 10° of a knee angle they found comfortable before performing their first jump (eliminating knee angle differences and therefore stance differences as a possible confounding factor). Although five jumps were performed, only data from the second, third, and fourth trials were used for analysis to avoid "body adjustments" and novelty or fatigue

3 Standing reach: subjects raise their arms directly above their head, reaching as far as possible while keeping feet on the ground.

4 Electrogoniometer: a tool used to measure joint angle and range of motion.

5 Vertec Vertical Jump Testing Apparatus: a tool used to measure vertical jump height.

effects that may occur at the beginning or end of the series (Marchetti & Uchida, 2011). Two perceptual scales, Borg's RPE scale (Borg, 1970) and a affect ("feeling") scale (Hardy & Rejeski, 1989), were administered after the first set of jumps. The RPE scale ranged from 6 to 20, with 6 indicating the no exertion and 20 indicating maximal exertion. The feeling scale ranged from -5 to +5, with -5 indicating the worst possible mood and +5 indicating the best possible mood. The first set of jumps plus the first set of perceptual scales comprised "Set 1."

Participants then ran two miles on a Sole TT8 treadmill (Sole Treadmill Co.) at a self-selected pace within the requirement of having to finish within twenty minutes. Subjects were discouraged from changing the pace during the trial, but not prevented from doing so. Immediately upon completion of the run, the two perceptual scales were administered again and comprised the "Post-Run" perceptual scales. The electrogoniometer was reattached and the subjects repeated the jumping protocol and perceptual scales as described prior to the run ("Set 2"). Thus the order of measurements was: Set 1, Post-Run, Set 2.

To statistically compare differences in jump height or perceptual scales between time points, one-way ANOVA tests were run using SPSS v. 20; IBM, Inc., and data was analyzed with Bonferroni corrections with the significance threshold at $\alpha=0.05$. Pearson correlations were used to determine relationships between jump height and other variables (knee angles, run time, run speed). All values are given as means ± standard deviations.

Results

Vertical jump height significantly increased from Set 1 to Set 2 (Fig. 1a; $p=0.019$). To test if this was due to "familiarization" with the jumping method from repeated practice during the study versus an actual effect of exercise, ANOVA was performed comparing the five jumps in the pre-run set and, separately, the five jumps in the post-run set; no significant differences were found within a set ($p=0.112$ and $p=0.764$ respectively). As expected, knee angles did not differ significantly between the two jump sets (Fig. 1b). The average time spent running was 17.0 ± 1.0 minutes. Total time spent running and knee angles during jump height never significantly correlated with jump height.

Subjects' RPE scores significantly increased from Set 1 to Post-Run (Fig. 2a; $p<0.001$) and significantly decreased from Post-Run to Set 2 (Fig. 2a; $p=0.002$), but were not significantly different between Set 1 and Set 2. Mirroring this, subjects' feeling scores significantly decreased from Set 1 to Post-Run (Fig. 2b; $p<0.001$) and significantly increased from Post-Run to Set 2 (Fig. 2b; $p=0.045$), but were not significantly different between Set 1 and Set 2.

Discussion

The study aimed to determine if a two-mile warm-up run would (a)

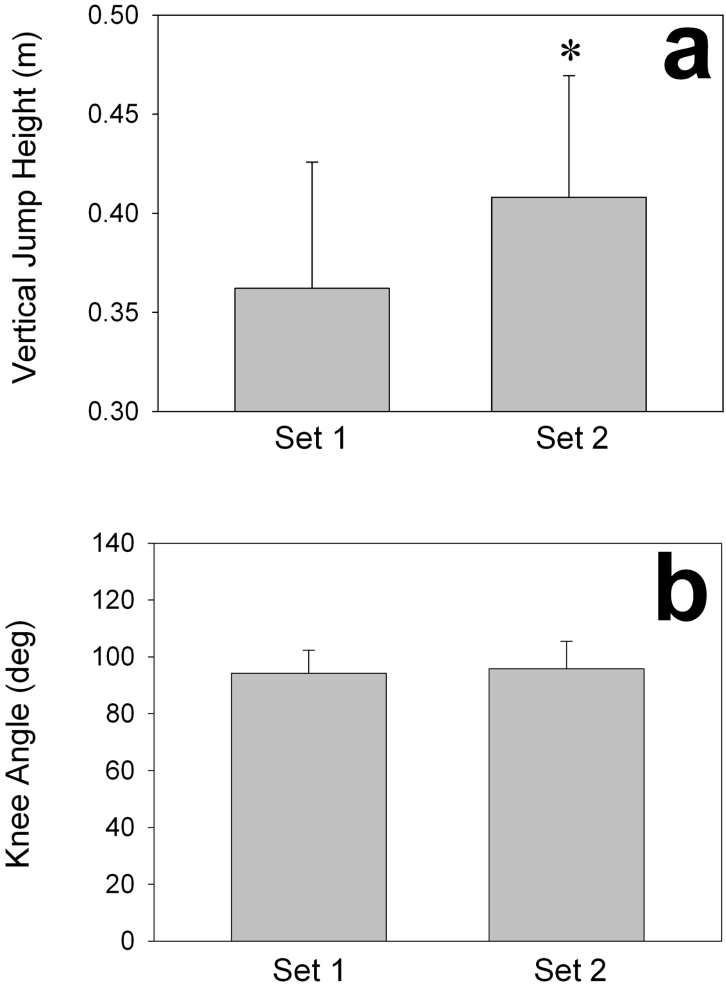

Figure 1. Physical measurements during the vertical jump: (a) jump height and (b) knee angle. Set 1 represents the jumps before running whereas Set 2 represents the jumps after running. Data are averages ± standard deviations. The asterisk (*) indicates a significant increase in jump height from Set 1 to Set 2.

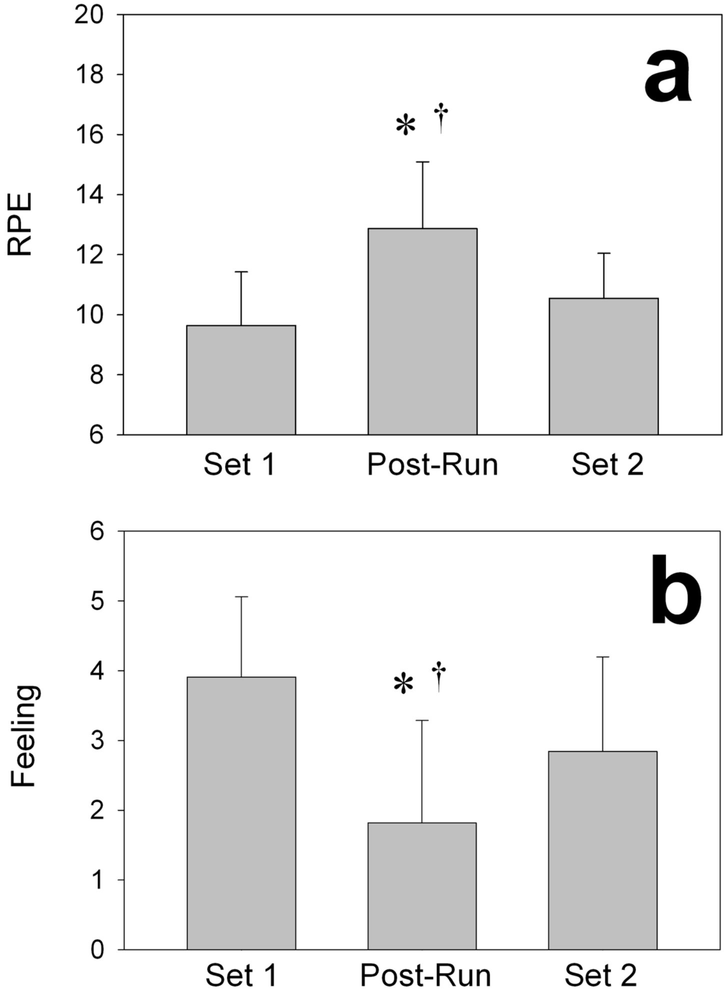

Figure 2. Perceptual measurements after the first set of jumps (Set 1), immediately after the run (Post-Run), and after the second set of jumps (Set 2): (a) RPE, (b) feeling (affect). Data are averages ± standard deviations. Asterisks (*) indicate a significant difference between Set 1 and Post-Run. Daggers (†) indicate a significant difference between Post-Run and Set 2.

increase or decrease maximum vertical jump height and (b) influence perceptual outcomes related to jump performance. Findings indicated that an acute warm-up running session of ~17 minutes significantly increased vertical jump height in college-aged females (Fig. 1). These results are consistent with the two running warm-up studies described earlier (Vetter, 2007; Young & Behm, 2003), but are novel because they show that long-distance runs can also improve vertical jump height. One difference between our study versus the previous two was that the distance was fixed in our study whereas the time was fixed in the previous studies. Different studies examining running and jumping as separate, distinct events have also shown a positive correlation between run performance times and jump performance (Comfort, Stewart, Bloom, & Clarkson, 2014; Shalfawi, Sabbah, Kailani, Tønnessen, & Enoksen, 2011), likely because both run performance and jump performance are determined by an athlete's power (Harries, Lubans, & Callister, 2012). The collective literature may provide a mechanical explanation for why we obtained these results and why our results were consistent with others' results.

For the perceptual scales, findings indicated that subjects' RPE was higher and their affect lower immediately after the run (Fig. 2). Research has shown that that RPE and affect have an inverse relationship in exercise, ranging from Tai Chi (Chao et al., 2014) to competitive triathlons (Parry, Chinnasamy, Papadopoulou, Noakes, & Micklewright, 2011). Thus, the present results of higher RPE and lower affect are consistent with the perception literature. Subjective perceptual responses can be readily influenced by external factors, such as baseline mood states (Parfitt, Evans, & Eston, 2012), presence of music (Hutchinson, Karageorghis, & Jones, 2014; Stork, Kwan, Gibala, & Martin Ginis, 2014), knowledge of the upcoming exercise (Baden, McLean, Tucker, Noakes, & St Clair Gibson, 2005; Swart et al., 2009), and even the sex of other personnel in the testing space (Winchester et al., 2012). This study controlled for these possible confounding variables by having a pre-study fifteen-minute rest period, prohibiting music, fully disclosing experimental procedures, and only having female personnel in the room during testing of female subjects.

Some limitations in study design are recognized and may serve as ways to refine similar experiments in the future. One limitation of this study was the lack of a non-running comparison group (individuals that jumped, sat for seventeen minutes without running, and jumped again). Although statistics indicated there was no familiarization effect from the jumping protocol, repeating the study with that group would more directly allow for the testing of possible familiarization. Subjects arrived in the lab wearing their own athletic clothing, so differences in clothing worn may have influenced results. For example, the amount of dorsiflexion a shoe imposes on the ankle may influence vertical jump performance (Faiss et al., 2010). Subjects may have felt some discomfort if they did not know the testing personnel well. As the subjects ranged from recreationally trained to currently competitive endurance athletes, both physical and psychological responses may have been influenced by former and current training backgrounds (Vetter, 2007).

Future research could grow from these findings. Having athletes from different sports perform similar protocols to look for differences across athlete types could expand upon these results. Further studies could involve splitting up sprint-trained, endurance-trained, and non-athletes to see whether a longer-distance running warm up is beneficial for each type of runner. Another option would be creating a long-term running program and measuring the changes in vertical jump height throughout the program. Given that a 2-mile run is taxing on athletes prior to competition (even when done at a self-selected pace, as it was done in this study), future work could test runs of different lengths to determine the shortest distance needed to achieve similar benefits.

In conclusion, this study found that an acute warm-up session of running two miles at a self-selected pace may significantly increase maximum vertical jump in college-aged females, despite the fact that the long run may make athletes feel “worse” (as evidenced by higher exertion and lower feeling scores). These findings are consistent with multiple studies investigating different dynamic warm-up strategies and may benefit certain athlete populations for whom centimeters of difference in vertical jump height are crucial in competition.

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