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Acute Effects of Different Warm-up Protocols on Fitness Performance in Children

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Abstract. Faigenbaum, A.D., M. Bellucci, A. Bernieri, B. Bakker, and K. Hoorens. Acute effects of different warm-up protocols on fitness performance in children. *J. Strength Cond. Res. 19(2): 376–381. 2005.*—The purpose of this study was to compare the acute effects on youth fitness of 3 different warm-up protocols utilizing static stretching or dynamic exercise performance. Sixty children (mean age 11.3 ± 0.7 years) performed 3 different warm-up routines in random order on nonconsecutive days. The warm-up protocols consisted of 5 minutes of walking and 5 minutes of static stretching (SS), 10 minutes of dynamic exercise (DY), or 10 minutes of dynamic exercise plus 3 drop jumps from 15-cm boxes (DYJ). Following each warm-up session, subjects were tested on the vertical jump, long jump, shuttle run, and v-sit flexibility. Analysis of the data revealed that vertical-jump and shuttle-run performance declined significantly following SS as compared to DY and DYJ, and long-jump performance was significantly reduced following SS as compared to DYJ ($p < 0.05$). There were no significant differences in flexibility following the 3 warm-up treatments. The results of this study suggest that it may be desirable for children to perform moderate- to high-intensity dynamic exercises prior to the performance of activities that require a high power output.

Key Words. youth, dynamic exercise, stretching, power, potentiation

Introduction

Children are often encouraged to participate in some type of warm-up before vigorous physical activity. Several minutes of low-intensity aerobic exercise followed by static stretching is generally recommended for young fitness participants. While static stretching has been found to enhance flexibility (increasing range of motion in the joints) and reduce muscle tension (1, 31), it is widely conjectured that pre-event protocols that include static stretching will also reduce the risk of injury and enhance performance (12, 26). Although convincing scientific evidence documenting the injury-reducing and performance-enhancing potential of static stretching is limited, static stretching has become a generally accepted pre-event procedure for younger and older populations (1, 30).

Over the past few years, long-held beliefs regarding the value of pre-event static stretching have been questioned, and increased attention has centered on the performance of higher-intensity movements during the warm-up period (4, 31). Although static stretching is a safe physical activity that will increase the range of motion at a particular joint (1, 27), studies indicate that an acute bout of static stretching can negatively affect subsequent strength or power performance in adults (2, 11, 21, 31). More recent observations show that an acute bout of static stretching can impair jumping performance in teenagers (17). Collectively, these findings suggest that pre-event static stretching has the potential to adversely affect muscle strength and power production.

Recently, there has been a renewed interest in warm-up procedures that involve the performance of low-, moderate-, and high-intensity dynamic movements that are designed to elevate core body temperature, enhance motor unit excitability, improve kinesthetic awareness, and maximize active ranges of motion (15, 23). This type of functionally based pre-event protocol is often referred to as dynamic exercise and typically includes hops, skips, jumps, and various movement-based exercises for the upper and lower body. Pre-event warm-up treatments that include plyometrics, heavy-load resistance exercise, or maximum voluntary contractions have been shown to positively influence muscle strength and power production in adults (9, 16, 30, 32). Although some observers suggest replacing pre-event static stretching with dynamic exercise (7, 23), research is needed to support such recommendations.

To date, no studies have compared the acute effects of a low-intensity warm-up using static stretching on fitness performance in children with the effects of moderate- to high-intensity warm-ups using dynamic exercise. Given the differing responses to various pre-event protocols in adults (2, 11, 21, 31) and recent observations noting the deleterious effects of static stretching on power performance in teenagers (17), there is a distinct need for research evaluating the effects of different warm-up treatments on children. This information would be useful to physical education teachers and youth coaches who typically encourage children to engage in some type of warm-up prior to exercise or sport.

The purpose of this investigation was to examine the acute effects of 3 different warm-up protocols on selected fitness measures in children. Specifically, we compared the effects of 3 different warm-up treatments using either static stretching or dynamic exercise on vertical jump, long jump, shuttle run, and flexibility performance. Because static stretching has been shown to have an adverse effect on muscle strength and power production in older populations, we hypothesized that a low-intensity pre-event protocol that includes static stretching would negatively affect fitness performance in children.

Methods

Experimental Approach to the Problem

In this study, we wanted to compare the acute effects of different warm-up protocols using static stretching or dynamic exercise on selected fitness measures in youth. A group of children performed 3 different warm-up protocols in random order on nonconsecutive days. The 3 warm-up protocols consisted of low-intensity aerobic exercise and static stretching, moderate- to high-intensity dynamic exercises, and moderate- to high-intensity dynamic exercises followed by 3 drop jumps. Following each warm-up routine, subjects performed 4 fitness tests designed to measure lower-body power, speed, and flexibility. All subjects were evaluated by members of the research team who had experience teaching and testing children. This design allowed us to individually assess fitness performance following each warm-up treatment and to carefully monitor the response of each subject to study procedures.

Subjects

Seventy children (34 girls and 36 boys) originally volunteered to take part in this study. Eight subjects (3 boys and 5 girls) did not complete all study procedures, and 2 girls with pre-existing knee injuries were not permitted to participate. No subject withdrew because of injury or other adverse experiences. The final sample consisted of 60 children (27 girls and 33 boys). The mean ± *SD* for age, height, and weight of subjects who completed all study procedures was 11.3 ± 0.7 years, 147.1 ± 8.9 cm, and 39.2 ± 7.7 kg, respectively. A majority of the subjects (77%) participated in after-school sport activities (principally soccer and swimming) and trained at least 3 days per week. The methods and procedures used in this study were approved by the Institutional Review Board for use of human subjects at the university, and informed consent was obtained from all subjects and their parents.

Warm-up Protocols

Prior to data collection, all subjects participated in 2 introductory sessions during which they practiced all warm-up procedures and fitness tests. This introductory period was designed to reduce the influence of any learning effects caused solely by the mechanics of performing study protocols. Each warm-up session lasted about 10 minutes. Subjects warmed up in groups of 15 to 20, and 2 physical education teachers supervised each warm-up period. All study procedures took place in a school gymnasium between 1000 and 1400 hours, and children were asked not to participate in any moderate to vigorous physical activity before each warm-up session. The 3 warm-up protocols were performed in random order and administered 2 to 4 days apart. For ease of discussion, the 3 warm-up protocols will be referred to as protocol A, protocol B, and protocol C.

Protocol A consisted of 5 minutes of walking and 5 minutes of static stretching focusing on the lower body. Subjects walked at a comfortable pace and then performed 6 static stretches (Table 1). More detailed descriptions of each stretch are available elsewhere (1). Subjects performed each stretch in a slow, deliberate manner with proper body alignment. Subjects held each stretch for 15 seconds at a point of mild discomfort, relaxed for 5 seconds, then repeated the same stretch for another 15 seconds before progressing to the opposite leg (when necessary). The stretching protocol used in this study was consistent with general flexibility recommendations for children and representative of a general warm-up routine used by physical education teachers (30). The design of this protocol did not allow us to isolate the effects of static stretching on fitness performance, because it was considered inappropriate for children to perform static stretching in a rested state without some type of aerobic warm-up.

TABLE 1. Stretching exercises.

1. Adductor stretch. In the seated position with an erect spine, touch soles of feet together, bend knees, and allow knees to drop.
2. Modified hurdlers stretch. In a seated position with one leg straight, place the other leg on the inside of the straight leg and reach forward.
3. Hip rotator stretch. In a supine position, cross one leg over the other, forming a figure 4, and flex both hips to or past 90° by pulling on the uncrossed leg.
4. Bent-over toe raise. From a standing position with the heel of one foot slightly in front of the toes of the other foot, dorsiflex front foot towards shin while leaning downward with upper body.
5. Quadriceps stretch. In the standing position with an erect spine, bend one knee and bring heel towards buttocks while holding the foot with one hand.
6. Calf stretch. In a standing position with feet staggered about 2 or 3 feet from a wall, lean against the wall with both hands, keeping the back leg straight and the front leg slightly bent.

TABLE 2. Dynamic warm-up exercises.

1. High-knee walk. While walking, lift knee towards chest, raise body on toes, and swing alternating arms.
2. Straight-leg march. While walking with both arms extended in front of body, lift one extended leg towards hands then return to starting position before repeating with other leg.
3. Hand walk. With hands and feet on the ground and limbs extended, walk feet towards hands while keeping legs extended then walk hands forward while keeping limbs extended.
4. Lunge walks. Lunge forward with alternating legs while keeping torso vertical.
5. Backward lunge. Move backwards by reaching each leg as far back as possible.
6. High-knee skip. While skipping, emphasize height, high-knee lift, and arm action.
7. Lateral shuffle. Move laterally quickly without crossing feet.
8. Back pedal. While keeping feet under hips, take small steps to move backwards rapidly.
9. Heel-ups. Rapidly kick heels towards buttocks while moving forward.
10. High-knee run. Emphasize knee lift and arm swing while moving forward quickly.

Protocol B consisted of 10 minutes of 10 dynamic exercises that progressed from moderate to high intensity (Table 2). Subjects performed each dynamic exercise for a distance of 13 m, rested about 10 seconds, and then repeated the same exercise for 13 m as they returned to the starting point. Subjects were continually instructed to maintain proper form (e.g., vertical torso, knees towards chest, up on toes) during the performance of the dynamic movements. This protocol was designed to be similar to warm-up protocols typically used to prepare athletes for sports participation (15).

Protocol C consisted of 10 minutes of 10 dynamic exercises (same as protocol B) followed by 3 drop jumps. About 1 minute following the dynamic warm-up, subjects stepped from a 15-cm box to the floor with both feet and then immediately jumped onto another 15 cm box placed about 80 cm away. This was repeated for a total of 3 jumps. Subjects were encouraged to jump off the floor as rapidly as possible to minimize ground contact time. Drop jumps were used in this study because the primary muscles controlling movements requiring stretch-shortening muscle actions become highly activated during the eccentric phase (3). Unpublished observations from our center suggest that a box height of 15 cm is safe and effective for youth plyometric training.

A secondary analysis was performed to assess the cardiorespiratory demand of the 3 warm-up protocols. Eleven randomly selected subjects (7 boys and 4 girls) wore portable heart rate monitors (Polar Electro Inc, Waterbury, NY) during each warm-up protocol. Monitors were attached to the children with a lightweight chest strap and wrist watch. Heart rate data were recorded every 5 seconds. After each session the monitors were interfaced with a computer and the heart rate data was downloaded for statistical analysis.

Fitness Tests

Power, speed, and agility were evaluated using the vertical jump, standing long jump, and shuttle run tests. Standardized protocols for fitness testing were followed according to methods previously described (10, 20, 24). Subjects were permitted to perform a countermovement (i.e., an active prestretch of the hip and knee extensors) prior to jumping vertically or horizontally. The best jump of 3 trials for the vertical jump and long jump was recorded to the nearest 0.5 cm, and the best time of 2 shuttle run trials was recorded to the nearest 0.1 second with a handheld stopwatch. Lower-back and hamstring flexibility was evaluated by the v-sit flexibility test, and the best score of 3 trials was recorded to the nearest 0.5 cm (20). Test-retest reliability intraclass R for the dependent variables was $R > 0.85$.

Following the completion of each warm-up protocol, subjects walked at a comfortable pace for 2 minutes prior to fitness testing. In order to facilitate testing procedures, subjects were tested in groups of 7 to 10. The same physical education teacher tested the same subjects following each warm-up treatment. All 3 testing sessions following warm-up protocols A, B, and C were made with identical equipment, positioning, technique, and test order (vertical jump, long jump, shuttle run, and flexibility). Subjects completed testing on a given fitness test before progressing to the next test. All subjects completed the fitness test battery in about 25 to 30 minutes. Testing procedures used in this study were designed to be similar to fitness testing procedures used in most physical education programs. All study procedures were completed within 9 days.

Statistical Analyses

Descriptive statistics (mean ± *SD*) for age, height, weight, heart rate, and fitness variables were calculated. Heart rate data was reported as $b \cdot min^{-1}$. Multivariate analysis of variance (MANOVA) with repeated measures was used to analyze differences between criterion measures following the 3 warm-up protocols. When a significant F value was achieved, post-hoc comparisons were accomplished via a least significant difference (LSD) test to identify specific differences between trials. Statistical power for the sample size used ranged from 0.16 to 1.0. Because performance curves for most motor performance tests are similar during childhood, data for boys and girls were combined in this study (28). Statistical significance was set at $p \leq 0.05$, and all analyses were carried out using the Statistical Package for the Social Sciences version 10.0 (SPSS, Inc. Chicago, IL)

TABLE 3. Fitness performance following 3 different warm-up protocols.†

	SS	DY	DYJ
Vertical jump (cm)	27.6 ± 5.7	29.2 ± 6.2*	29.4 ± 6.0*
Long jump (cm)	147.6 ± 16.3	149.3 ± 16.3	150.4 ± 16.1*
Shuttle run (s)	11.3 ± 0.7	11.1 ± 0.7*	11.0 ± 0.7*
Flexibility (cm)	1.9 ± 8.3	2.4 ± 7.9	1.5 ± 8.7

* $p < 0.05$ vs. SS.

† SS = static stretching; DY = dynamic exercise; DYJ = dynamic exercise plus drop jumps. Data are presented as mean ± *SD*.

RESULTS

Means and standard deviations for all fitness test data are presented in Table 3. Vertical-jump and shuttle-run performance declined significantly following protocol A, which included static stretching, as compared to protocols B and C, which included dynamic exercise ($p = 0.001$). Long-jump performance was significantly lower following protocol A as compared to protocol C ($p = 0.021$). There were no significant differences in v-sit flexibility between the 3 warm-up conditions ($p = 0.34$).

No significant order effects were observed for vertical-jump or long-jump performance over the 3 testing trials ($p = 0.559$ and 0.214, respectively). Shuttle run times during the second testing session were significantly faster than during the first testing session ($p = 0.012$), and flexibility scores were significantly improved following the third testing session as compared to the first and second testing sessions ($p = 0.001$).

The mean heart rate responses to warm-up protocols A, B, and C were 108.8 ± 10.7 $b \cdot min^{-1}$, 149.8 ± 11.1 $b \cdot min^{-1}$, and 152.0 ± 12.7 $b \cdot min^{-1}$, respectively. The heart rate response to protocol A was significantly lower than during protocols B and C ($p = 0.001$).

DISCUSSION

The results of this study demonstrate that warm-up procedures can have a significant influence on fitness performance in children. We provide evidence that pre-event low-intensity aerobic exercise and static stretching may be suboptimal for preparing children for activities that require a high power output. In this investigation, performance in the vertical jump, long jump, and shuttle run decreased by 6.5%, 1.9% and 2.6%, respectively, following low-intensity aerobic exercise and static stretching as compared to warm-up treatments with moderate- to high-intensity dynamic movements. These data are important to help identify the most effective warm-up protocols for youth fitness testing and sports competition. To our knowledge, no other study involving children has compared the effects of a low-intensity warm-up with static stretching to moderate- to high-intensity warm-ups with dynamic exercise.

Our findings support previous investigations that found that an acute bout of static stretching can reduce power performance in adults (5, 11, 19, 32, 33). Cornwell et al. (5) reported that pre-event static stretching significantly reduced jump height by about 4.4%, and similar observations were made by Young and Behm (32) and Young and Elliot (33), who reported significant differences in explosive force and jumping performance following static stretching. Our data are also consistent with recent findings from McNeal and Sands (17), who observed that static stretching lowered jumping performance by 9.6% in teenage gymnasts.

Fowles et al. (6) noted that 30 minutes of passive stretching induced a significant decrease in motor unit activation 5 minutes after stretching and a reduction in strength that persisted for 60 minutes. These observations suggest that pre-event static stretching may influence neural mechanisms that may negatively affect muscular performance for a prolonged period of time. In our investigation, the most remarkable consequence of the pre-event protocol that included low-intensity aerobic exercise and static stretching was on vertical-jump performance (lower by 6.5%), which was assessed about 2 minutes after static stretching. By comparison, long-jump performance and shuttle-run speed (reduced by 1.9% and 2.6%, respectively) were assessed after the vertical-jump test and about 10 to 20 minutes after each warm-up session. Although speculative, it appears that the time interval between the completion of the warm-up protocol and the initiation of each fitness test may have influenced our findings. However, it is possible that the performance of one or more of the fitness tests may have influenced the performance on subsequent tests.

Several investigators have reported a reduction in force production following various static stretching protocols in adults (2, 6, 11, 21). Although the precise mechanisms responsible for these findings have not yet been elucidated, it has been proposed that a decrease in muscle activation or a reduction of passive or active stiffness of the musculotendinous unit may be partly responsible (2, 11). By decreasing musculotendinous stiffness, stretching may place the contractile elements in a position that is less than optimal for generating force rapidly. The pre-event stretching treatment used in our study may have prevented the lower-extremity musculature from functioning within the most desirable segments of their length:tension relationship.

In a majority of the aforementioned studies, the effects of static stretching were compared to a control condition without pre-event stretching, whereas in our investigation a low-intensity warm-up with static stretching was compared with higher-intensity warm-ups with dynamic exercise. Our data show that 10 minutes of moderate- to high-intensity dynamic exercise positively influenced power performance in children. Gullich and Schmidtbleicher (9) reported that high-intensity contractions performed during a pre-event warm-up enhanced counter-movement jump height by 3.3% in adult athletes and Young et al. (34) demonstrated that jump performance improved 2.8% when it was preceded by 1 set of half squats with a 5 repetition maximum (5RM) load. It has been suggested that pre-event moderate- to high-intensity contractions may excite the central nervous system, which in turn will allow for greater explosive effort during subsequent exercises (29).

Although further study is warranted, pre-event moderate- to high-intensity dynamic exercise may create an optimal environment for explosive force production by enhancing neuromuscular function. This phenomenon has been referred to as ‘postactivation potentiation” (PAP) and is believed to improve speed and power performance by increasing the rate of force development (25). Since PAP appears to have its greatest affect on fast-twitch fibers (8, 13), it is mostly likely to affect activities such as jumping and throwing. One could speculate that some of the pre-event moderate-intensity (e.g., high knee skip) and high-intensity (e.g., high knee run) dynamic exercises used in our study enhanced the excitability of the fast-twitch units and therefore “primed” these units to play a more significant role during jumping and sprinting activities. While this suggestion is consistent with the work of others who reported that dynamic-type loading facilitated the function of the neuromuscular system without undue fatigue (14), no tests on neuromuscular activation were performed in our investigation.

The influence of different dynamic warm-up treatments on jumping and sprinting performance was examined by adding 3 drop jumps to 1 of the dynamic warm-up protocols. Interestingly, there was no significant difference in long-jump performance following pre-event static stretching and pre-event dynamic exercise without drop jumps. However, performance in the long jump following dynamic exercise with drop jumps was significantly greater than following the treatment with static stretching.

These results suggest that there is some advantage to performing high-intensity drop jumps prior to activities that require a high power output. It is possible that the drop jumps activated additional neural pathways and enhanced to a greater degree the readiness of the neuromuscular system. While the potential impact of warm-up treatments on performance appear to fade over time (6), our findings suggest that there may be some advantage to incorporating high-intensity movements into the warm-up protocol. Although additional research is needed to explore the mechanisms and time-course of this impact, the possibility exists that warm-up protocols consisting of more intense exercises would optimize performance for longer periods of time. Only 3 drop jumps were used in our study because the children had limited experience performing these movements.

Our findings suggest that prior to the performance of activities which require a high power output, children should perform moderate- to high-intensity dynamic exercises. Although the practical significance of the magnitude of the impact may be questioned, the observed changes may be important in events in which success is dependant on a high power output. In our study, jumping performance improved 1.8 to 2.8 cm and sprinting ability improved by 0.2 to 0.3 seconds following dynamic warm-up treatments. In sports such as track and field, improvements such as these can have a notable impact on the outcome of the event. Nevertheless, because chronic improvements in flexibility may enhance performance in some sports (e.g., gymnastics), the requirements of each sport need to be evaluated so that the warm-up treatment is consistent with the needs of the athlete.

There was no significant difference in v-sit flexibility scores following the 3 warm-up treatments used in our study. Although a potential benefit of static stretching is an increase in joint range of motion, our findings suggest that dynamic exercise may be just as effective. However, it is possible that vertical-jump, long-jump, and shuttle-run testing influenced performance on the flexibility test, which was performed about 20 to 25 minutes after the warm-up treatments. Further, different static stretching exercises and treatments (e.g., upper-body stretches, longer stretch durations) may not yield the same results as observed in this investigation. The chronic effects of static and dynamic warm-up procedures were not examined in this study.

In terms of cardiorespiratory demand, the dynamic warm-up protocols elicited an average heart rate of about 150 $b \cdot min^{-1}$, whereas heart rates during the warm-up treatment with low-intensity aerobic exercise and static stretching averaged about 109 $b \cdot min^{-1}$. Although heart rate can be influenced by other factors such as emotional stress, heart rate data does provide an adequate indication of the relative stress placed on the cardiorespiratory system during physical activity (22). Our findings suggest that warm-up protocols that include dynamic exercise may not only enhance fitness performance, but may also increase the amount of time children engage in moderate to vigorous physical activity, which is an important public health objective (18).

A limitation of our study is that we did not have a control condition from which to compare the other warm-up treatments. However, it was considered inappropriate for children to participate in fitness testing procedures in a completely rested state. Another concern is that the order of the fitness tests was not randomized in our study. Thus, it is possible that performance on one fitness test may have influenced—either positively or negatively—the performance on subsequent tests. We recognize that the lack of randomization of the 4 fitness tests may complicate the interpretation of our findings.

Practical Applications

Although stretching may have an important role in the rehabilitation of injuries, our findings provide provocative evidence that pre-event protocols that include static stretching may be suboptimal for maximizing fitness performance in children. This is not to say that static stretching should be eliminated from a child's fitness program, but rather that coaches and teachers should consider the potential impact of pre-event treatments on fitness testing and sports performance. Unique to this investigation, power production in children was improved following moderate- to high-intensity dynamic warm-up treatments that lasted about 10 minutes.

Because convincing scientific evidence supporting the injury-reducing and performance-enhancing potential of static stretching is presently lacking, it may be desirable for children to perform dynamic exercises during the warm-up period and static stretching during the cool-down period. Alternatively, children could perform both static stretching and dynamic exercise during the warm-up period. However, these suggestions are tentative because the chronic effects of pre-event dynamic exercise on health and performance have not yet been examined.

Future studies should look at the acute and chronic effects of different dynamic warm-up treatments on strength and power production in children and should explore the impact of varying the warm-up intensity, duration, and recovery time on fitness performance. In addition, research is needed to examine the precise underlying neuromuscular mechanisms that may explain the performance-enhancing effects of pre-event dynamic exercise. This research will lead to improved methods of preparing youth for exercise and sport.

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