Reducing Warm-up Decrement in the Performance of the Tennis Serve

Mark H. Anshel
University of Wollongong

Craig A. Wrisberg
The University of Tennessee, Knoxville

In the present study an attempt was made to determine the relative effectiveness of various warm-up activities in eliminating postrest warm-up decrement (WUD) in the tennis serve. Seventy highly-skilled players hit 20 serves, rested for either 5 or 15 min, and then attempted 4 final serves. During the last 2 min of the rest period, players continued to rest, ran in place, engaged in mental imagery, performed practice swings, or repeatedly hit the ball against the ground and caught it. In addition to estimates of serving accuracy, measures of somatic and cognitive arousal were obtained at the beginning and end of the rest interval. Multiple regression procedures revealed that reductions in WUD were significantly related to the restoration of prerest arousal levels. Between-group comparisons indicated that practice swings were the most effective warm-up activity for restoring somatic and cognitive arousal to prerest levels and for eliminating WUD. Theoretical discussion centered on possible applications of Nacson and Schmidt’s (1971) activity-set hypothesis to the tennis serve.

Key words: mental imagery, physical practice, rest, somatic and cognitive arousal

One of the most pervasive phenomena in the domain of human motor behavior is the temporary decrement in performance that occurs following an interval of rest. This phenomenon, termed warm-up decrement (WUD), is usually brief in duration, lasting for only the first few trials of postrest performance. Because WUD has been shown to be reduced or eliminated by the practice of interpolated tasks that presumably contribute little to the memory strength of the criterion task (e.g., Wrisberg, Salmoni, & Schmidt, 1975), it has been assumed that WUD is not due to forgetting the criterion response but rather to inappropriately readjusting underlying mechanisms that support criterion-task performance (Adams, 1961).

Mark H. Anshel is with the Department of Psychology at the University of Wollongong, Wollongong, New South Wales, Australia 2522. Craig A. Wrisberg is with the Department of Human Performance and Sport Studies at the University of Tennessee, 344 HPER, Knoxville, TN 37996-2700.
Of the various theoretical accounts for WUD (for reviews see Adams, 1961; Schmidt, 1972), the one receiving the most empirical support has been the activity-set hypothesis (Ainscoe & Hardy, 1987; Anshel & Wrisberg, 1988; Schmidt & Nacson, 1971; Schmidt & Wrisberg, 1971), proposed by Nacson and Schmidt (1971). According to this hypothesis, motor skill practice serves, among other things, to adjust relevant systems (e.g., attentional focus, arousal level, speed–accuracy trade-off requirements) that underlie task performance. A brief bout of rest, however, usually results in the readjustment of one or more of these systems. For example, during a change of side in tennis, the attentional focus of a player might shift from an external orientation required for successful visual tracking of the ball to an internal one that is conducive to keeping track of first-serve percentage. If appropriate adjustment of attentional focus (or of other systems comprising the activity set for tennis) does not occur prior to the resumption of play, then WUD may result (e.g., in serving or receiving). In summary, then, WUD is presumed to be due to an insufficient readiness to respond that occurs when relevant support systems (i.e., the activity set) are not properly readjusted following a rest interval.

Tests of the activity-set hypothesis have typically involved a paradigm in which various warm-up activities are inserted at the end of a rest period prior to the resumption of performance on the criterion task. If a particular warm-up activity appropriately adjusts an underlying component of the activity set for the task, then a reduction in postrest WUD (relative to that of a no warm-up control condition) should occur.

One underlying system that appears to be a part of the activity set for a number of tasks is arousal level. Usually associated with the intensity dimension of behavior, arousal has in recent years been examined as a multidimensional concept. Somatic (physiological) arousal refers to a “state of activation of the autonomic nervous system (e.g., heart rate or blood pressure) on a continuum from deep sleep to high excitement” (Anshel et al., 1991, p. 113). Cognitive (psychological) arousal, on the other hand, is the “heightened state of alertness and readiness on a continuum from deep sleep to extreme excitement [and] may include positive or negative emotions” (Anshel et al., 1991, p. 121). The results of several studies have revealed that groups performing warm-up tasks designed to readjust levels of somatic arousal demonstrate significantly less WUD during postrest performance relative to a no-warm-up control condition. For example, Anshel (1985) and Anshel and Wrisberg (1988) found that WUD (for gymnastics vaulting and baseball batting, respectively) was eliminated when subjects engaged in a warm-up that involved bicycle ergometer work at 50% maximum heart rate. Although warm-up tasks in these two studies were designed to increase arousal levels relative to those associated with rest conditions, it is possible that, in some situations, arousal may need to decrease in order to facilitate subsequent performance. For example, a golfer may need to diminish her arousal level before attempting a putt following a two-iron shot to the green. Although Nacson and Schmidt (1971) conceptualize the activity set as a “generalized preparation to respond” (p. 3), it would appear that studies exploring the importance of arousal adjustments in reducing WUD need to differentiate somatic and cognitive components. In the present experiment, somatic arousal was estimated by monitoring heart rate while positive and negative components of cognitive arousal were
Anshel and Wrisberg operationalized by obtaining subjects’ responses on an adult version of the Children’s Arousal Scale (CAS-A; Anshel, 1985).

Another possible component of the activity set is mental imagery. The results of research exploring this possibility indicate that reductions in WUD following an imagery warm-up occur for some tasks but not for others. Ainscoe and Hardy (1987) found that the WUD of gymnasts was eliminated in the performance of double leg circling on the pommel horse after subjects warmed up by imaging themselves correctly performing the task. However, Anshel (1985) found no influence of positive imaging on postrest WUD for the handspring vault. Anshel and Wrisberg (1988) observed reductions in WUD in baseball batting for subjects who engaged in relevant imagery (e.g., visualizing the release of the ball from the pitcher’s hand and the moment of impact with the bat), but not for those who practiced irrelevant imagery (e.g., visualizing the trajectory of an approaching fly ball followed by a successful catch) as a warm up.¹

Taken together, the available evidence suggests that some support systems (e.g., arousal) may be a part of the activity set for a variety of tasks whereas others (e.g., mental imagery) may have a more limited usefulness. In the present study the tennis serve was used as the criterion task, and warm-up activities were selected that were reasoned to be possible candidates for the activity set. Advanced tennis players performed serves by hitting balls toward a designated target situated in the ad court. Following initial trials, subjects rested and then, during the last 2 min of this period, continued to rest or performed one of four warm-up activities.

One of the warm-up activities was designed to increase somatic arousal (i.e., running in place), whereas another was intended to create a successful mental picture of the correct serve (i.e., imagery). The remaining two warm-up activities involved separate components of the criterion task that could be performed by players within the rules of competitive tennis. One emphasized the mechanics of the serving motion (i.e., practice swings without the ball), whereas the other contained hand–eye coordination requirements (i.e., striking the ball toward the ground and then catching it). It should be noted that the latter two tasks represent a modest departure from the kinds of warm-up activities employed in most laboratory investigations of the activity-set hypothesis. Because the two activities simulate quasi-components of the serve itself, it might be argued that they contribute memory strength to the serve rather than adjust underlying nonhabit mechanisms. However, it was reasoned that high-performance athletes such as those used in the present study would be likely to derive little in the way of increased memory strength for the serve (which they have probably executed thousands of times previously) from short bouts of isolated practice swings or ball striking.

A secondary purpose of the present investigation was to determine the effect of rest interval length on WUD. The majority of previous studies have involved fixed periods of rest ranging from 10 min (Nacson & Schmidt, 1971; Schmidt & Nacson, 1971; Schmidt & Wrisberg, 1971) to 20 min (Anshel, 1985) in length. In a more recent experiment, Wrisberg and Anshel (1993) employed rest intervals of 5 and 15 min and found no significant differences in the tennis groundstroke as a function of rest interval length. However, additional research with a variety of tasks is needed to determine whether postrest decrements in performance differ as a function of length of the rest period. Therefore, in the present study subjects rested for either 5 or 15 minutes between criterion performance periods.
Method

Subjects

The subjects were male \( n = 55 \) and female \( n = 15 \) tennis players from New South Wales, Australia, who had competed in at least one state-level tournament. Subjects ranged in age from 19.2 to 26.7 years \( (M = 23.8) \). Prior to participation in the study, players were subjectively rated by two tennis instructors on their ability to hit the serve consistently over the net and into a designated target area using the proper technique. A 5-point Likert scale was employed with scores ranging from 0 (poor) to 5 (excellent). Only those players receiving a rating of 4 or higher by both judges (interrater \( r = .94 \)) were selected as subjects. The range of scores for the subjects who qualified for the study was 4.12 to 4.90.

Apparatus

Measures of somatic and cognitive arousal were obtained at various times during testing. Somatic arousal was inferred by using a Sports Tester 3000 Heart Rate Monitor to record the heart rates of subjects. Estimates of cognitive arousal were determined by administering an adult version of the Children’s Arousal Scale (CAS-A; Anshel, 1985). The CAS-A was chosen over other sport-related scales (e.g., CSAI-2; Martens, Burton, Vealey, Bump, & Smith, 1990) because it could be administered quickly and contained no reference to competitive conditions. The CAS-A is a 7-point semantic differential scale designed to measure general state arousal based on perceived emotions accompanying experiences of success and failure. It consists of four items associated with positive arousal (e.g., happy, relaxed) and six items related to negative arousal (e.g., worried, nervous). Subjects are asked to indicate the extent to which each item describes the way they feel at the present time. A Pearson Product-Moment scale intercorrelation revealed a low positive relationship between positive and negative arousal items \( (r = .30) \). Internal consistency of the total scale (Cronbach’s alpha = .79) had been previously established (Anshel, 1985) and was reaffirmed in the present study (Cronbach’s alpha = .81).

Criterion Task

The criterion task involved serving a tennis ball from a location 2 ft (.61 m) to the left of the center mark into a designated target area located in the ad service court. The target consisted of a rubber mat covering a rectangular area bounded by the service line, the center line, and two additional lines, one located 3 ft (.91 m) from the service line and the other 2 ft (.61 m) from the center line. The objective on each shot was to hit the ball into the ad court as close to the target area as possible.

Interpolated Tasks

Subjects performed one of the following tasks during the last 2 min of the rest interval. The 2-min interval was monitored using a stopwatch. Verbal commands (e.g., “go”) and heart rate feedback were provided by an experimenter at predetermined moments.
The experimental arrangement consisted of three phases: 20 initial periods. The signal, located on the perimeter of the large area, served to indicate the location of the ball inside the ball and was used to determine the position of the ball. For each trial, a team of two experimental subjects watched the location of the ball, and the location was used to determine the position of the ball. The proportion of correct responses was determined for each phase of the experiment, and the proportion of correct responses was determined for each phase of the experiment. The proportion of correct responses was determined for each phase of the experiment. The proportion of correct responses was determined for each phase of the experiment.
During the first 10 s of the rest period, subjects’ heart rates were monitored. Immediately after this, they completed the CAS-A. During the remainder of the rest period, subjects were seated and read an article from a tennis magazine that detailed competitive strategies used by well-known professional players. This activity was designed to prevent mental rehearsal of the criterion task. To assure that subjects read the material, they were told that several questions would be asked about the contents of the article at the completion of testing. All subjects were asked between two and four questions, depending on the length of their answers. During the last 2 min of the rest period, treatment subjects engaged in their respective warm-up activities, while control subjects continued to read. Following the rest period, heart rate was again monitored and the CAS-A was completed. Subjects then performed four final trials of the serve.

The entire experimental protocol was completed twice by each subject, once for each length of rest period (5 and 15 min). The order of rest periods was counterbalanced among subjects in each condition with 7 subjects receiving a 5-min rest during the first round and a 15-min rest during the second while the remaining 7 received the opposite order.

**Results**

**Performance Accuracy**

Since preliminary analyses revealed no significant effect of rest interval length during prerest performance, a $5 \times 20$ (Groups $\times$ Trials) ANOVA with repeated measures on the second factor was performed on mean prerest performance accuracy scores (Figure 1). Where appropriate, omega squared ($\omega^2$) was calculated to determine the meaningfulness of significant differences (Tolson, 1980). The results revealed significant effects for groups, $F(4, 65) = 5.10, p < .01$, $\omega^2 = .01$; trials, $F(19, 1235) = 338.69, p < .01$, $\omega^2 = .76$; and the Groups $\times$ Trials interaction, $F(76, 1235) = 2.80, p < .01$, $\omega^2 = .02$. Simple main effects analysis of the Groups $\times$ Trials interaction revealed that Group Strike was significantly ($p < .05$) more accurate than Groups Swing, Run, and Control on the first two prerest trials. However, no significant between-group differences existed on any other trials. Thus, it was assumed that the performance of all groups was equivalent immediately prior to the rest interval.

Postrest performance accuracy was evaluated by a $5 \times 2 \times 5$ (Groups $\times$ Rest Intervals $\times$ Trials) ANOVA with repeated measures on the last two factors. Trial 20 of prerest performance was included in the analysis to determine the magnitude and pattern of postrest WUD in the various groups. Follow-up tests using simple main effects analysis and Tukey’s procedure were conducted to locate the source of any significant differences. Significant effects were obtained for groups, $F(4, 65) = 47.39, p < .01$, $\omega^2 = .17$; trials, $F(4, 520) = 415.30, p < .01$, $\omega^2 = .42$; the Groups $\times$ Trials interaction, $F(16, 520) = 44.38, p < .01$, $\omega^2 = .17$; and the Groups $\times$ Rest Intervals interaction, $F(4, 65) = 10.31, p < .01$, $\omega^2 = .01$.

Follow-up tests of the Groups $\times$ Trials interaction (see Figure 2) revealed significant differences between groups on Trials 21, 22, and 23, $F(4, 65) = 89.75, p < .01$, $\omega^2 = .77$; $F(4, 65) = 19.92, p < .01$, $\omega^2 = .40$; and $F(4, 65) = 12.63, p < .01$, $\omega^2 = .28$, respectively, but not on Trials 20 (last prerest trial) or 24, $F(4, 65) = .65, p > .05$, and $F(4, 65) = 1.88, p > .05$, respectively. For Trial 21, all
warm-up groups demonstrated significantly higher performance accuracy (i.e., less error) than Group Control ($M = 54.89$, $SD = 12.87$). In addition, Group Swing ($M = 8.61$, $SD = 4.46$) was significantly more accurate than Groups Strike ($M = 25.75$, $SD = 5.67$), Run ($M = 32.21$, $SD = 8.05$), and Image ($M = 35.18$, $SD = 7.30$), and Group Strike was more accurate than Group Image.

This pattern persisted on Trial 22 as Group Control ($M = 30.39$, $SD = 11.07$) was significantly less accurate than all warm-up groups, whereas Group Swing ($M = 10.25$, $SD = 3.34$) exhibited significantly more accuracy than Groups Run ($M = 19.86$, $SD = 8.24$), Strike ($M = 17.43$, $SD = 5.87$), and Image ($M = 22.75$, $SD = 8.07$). By Trial 23, the only significant differences were between Group Swing ($M = 6.18$, $SD = 3.39$) and the other groups (Strike, $M = 12.96$, $SD = 4.49$; Run, $M = 13.57$, $SD = 5.86$; Image, $M = 14.57$, $SD = 7.81$; Control, $M = 16.82$, $SD = 4.97$).

Within-group analyses of performance accuracy across the 5 trials revealed a classic pattern of WUD for Groups Control, Image, and Strike, $F(4, 104) = 176.29, p < .01, \omega^2 = .81$; $F(4, 104) = 147.86, p < .01, \omega^2 = .68$; and $F(4, 104) = 78.01, p < .01, \omega^2 = .63$, respectively. For all three groups, performance was significantly ($p < .05$) less accurate on Trials 21, 22, and 23 than on Trials 20 and 24. A significant trials effect was also found for Group Run, $F(4, 104) =
Figure 2 — Error scores for the last prerest trial and all postrest trials of the tennis serve.

70.36, \( p < .01, \omega^2 = .61 \). For this group, performance accuracy on Trials 21 and 22 was significantly lower than that on Trials 20, 23, and 24. Perhaps most impressive, however, was the absence of a significant trials effect for Group Swing.

Post hoc inspection of the Groups × Rest Intervals interaction revealed a significant effect of rest interval length only for Group Image, \( F(1, 26) = 18.39, p < .01, \omega^2 = .07 \). The performance accuracy of this group was significantly \( (p < .05) \) lower after the 15-min interval \( (M = 21.63, SD = 12.49) \) than after the 5-min interval \( (M = 15.41, SD = 9.65) \).

In summary, the analysis of performance accuracy scores indicated that practice swings was the only warm-up activity that eliminated WUD. Although the amount of WUD in the postrest performance of the other warm-up groups was less than that of the control condition, patterns of recovery from WUD were similar.
Table 1
Prerest and Postrest Scores for Heart Rate, CAS-A Positive, and CAS-A Negative

<table>
<thead>
<tr>
<th>Group</th>
<th>Rest interval</th>
<th>Heart rate</th>
<th>CAS-A positive</th>
<th>CAS-A negative</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Prerest</td>
<td>Postrest</td>
<td>Prerest</td>
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<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Control</td>
<td>5</td>
<td>107</td>
<td>11</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>110</td>
<td>9</td>
<td>62</td>
</tr>
<tr>
<td>Swing</td>
<td>5</td>
<td>103</td>
<td>10</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>15</td>
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<td>9</td>
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<tr>
<td></td>
<td>15</td>
<td>104</td>
<td>9</td>
<td>72</td>
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<tr>
<td>Strike</td>
<td>5</td>
<td>102</td>
<td>12</td>
<td>88</td>
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<tr>
<td></td>
<td>15</td>
<td>101</td>
<td>11</td>
<td>78</td>
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<tr>
<td>Run</td>
<td>5</td>
<td>111</td>
<td>10</td>
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<td>104</td>
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Somatic and Cognitive Arousal

In order to determine the influence of the various warm-up activities on somatic and cognitive arousal, separate 5 x 2 (Groups x Rest Intervals) ANOVAs with repeated measures on the second factor were performed on difference scores calculated for heart rate, CAS-A positive, and CAS-A negative measures. Each score was determined by subtracting the value obtained at the end of the rest interval from that obtained at the beginning. Descriptive statistics for these three measures as a function of warm-up condition and rest interval length are presented in Table 1. For heart rate, significant effects were found for groups, \( F(4, 65) = 86.76, p < .01, \omega^2 = .73; \) rest intervals, \( F(1, 65) = 108.35, p < .01, \omega^2 = .05; \) and the Groups x Rest Intervals interaction, \( F(4, 65) = 24.98, p < .01, \omega^2 = .05. \) Post hoc analysis of the groups effect using Tukey’s procedure revealed that (a) the pre–post difference for Group Control was significantly \((p < .05)\) greater than that of all warm-up conditions, (b) the difference for Group Image was significantly greater than that of the other warm-up conditions, and (c) the difference for Group Strike was significantly greater than that for Groups Run and Swing.

Thus, it appeared that all warm-up activities increased somatic arousal when compared to the no-warm-up control condition and that only running in place and practice swings restored heart rate to prerest levels. With respect to the significant rest intervals effect, heart rate decreased more over the longer rest period than over the shorter one. However, simple main effects analysis of the Groups x Rest Intervals interaction revealed that only Group Control and Group Image had significantly \((p < .05)\) greater decreases in heart rate over the 15-min interval than over the 5-min interval. These results indicate that, of the various warm-up activities, imagery was the least effective in restoring somatic arousal.
A significant effect of groups was found for both CAS-A positive and CAS-A negative scores, $F(4, 65) = 18.31, p < .01, \omega^2 = .46$, and $F(4, 65) = 36.65, p < .01, \omega^2 = .57$, respectively. For the former measure, only Group Control experienced a reduction in positive arousal. The results of the post hoc test revealed significant ($p < .05$) differences between this group and all warm-up conditions and between Group Swing (which had the largest increase in positive arousal) and the other warm-up conditions. For CAS-A negative scores, Group Control was the only one to report an increase. Post hoc results indicated that the score of this group was significantly ($p < .05$) different from those of all warm-up conditions and that the score of Group Swing (which had the largest decrease in negative arousal) was significantly different from those of the other warm-up conditions, with the exception of Group Strike. Taken together, these findings suggest that all warm-up activities restored cognitive arousal to levels found near the end of initial performance trials, with the most prominent influence resulting from practice swings.

To determine the extent of relationship between arousal level and immediate postrest performance, multiple regression analyses were performed for each rest interval condition using the difference scores for the three arousal measures as predictor variables and using the performance accuracy score on Trial 21 as the dependent variable. The $R$-square selection method (Freund & Littell, 1991) and Mallows's (1973) $C(p)$ statistic were used to determine the most useful subset model for each rest interval. For the 5-min interval, a three-term model was identified in which the interaction of heart rate and CAS-A positive scores was the best predictor of postrest performance ($R^2 = .46$) followed by heart rate ($R^2 = .53$) and finally by the interaction of CAS-A positive and CAS-A negative scores ($R^2 = .59$). For the 15-min interval, a two-term model was selected in which heart rate was the best predictor of postrest performance ($R^2 = .49$) followed by CAS-A negative scores ($R^2 = .64$). Tests for multicollinearity revealed small variable inflation factor values (VIFs < 2) for both models. Taken together, these results suggest that, for both the shorter and longer rest intervals, postrest serving accuracy was higher when postrest somatic arousal approached or surpassed prerest arousal levels. To a lesser degree, maintenance of positive cognitive arousal was related to higher performance following the shorter interval, whereas suppression of increased negative cognitive arousal was associated with serving accuracy following the longer interval.

**Discussion**

In the present study an attempt was made to determine the relative effectiveness of various warm-up activities in reducing postrest performance decrement (referred to as warm-up decrement, or WUD) in the tennis serve. In addition, an effort was made to determine (a) the influence of different warm-up tasks on somatic and cognitive arousal, and (b) whether the length of the rest interval interpolated between performance bouts influences WUD. Experienced players performed 20 serves aimed at a designated target area in the ad court. They then rested for 5 or 15 min, the last two of which involved additional rest or the performance of one of four warm-up activities. Each warm-up task (a) emphasized a possible support system (Nacson & Schmidt, 1971) underlying performance
of the serve and (b) was considered practical for use by players under normal competitive conditions.

Although the prerest performance accuracy of all groups was comparable, WUD was evidenced in the immediate postrest performance of the no-warm-up control condition as well as that of the warm-up groups that mentally imaged successful performance of the serve, hit the ball against the ground and caught it, and ran in place. The only warm-up task that eliminated postrest WUD was that involving practice swings of the serve. Interestingly, this activity also produced significantly greater restorations of positive cognitive arousal and, except for running in place, somatic arousal and a significantly greater reduction of negative cognitive arousal than did all other rest-interval activities.

The most plausible explanation for the superiority of practice swings as a warm up was that it involved an activity that was more similar to the criterion task, even though no ball was used during the performance of this task. For closed skills (Poulton, 1957) like the tennis serve, in which a high degree of environmental stability exists, the performer is able to devote more attention to response selection and execution. Therefore, it should not be surprising that the best warm up is one that simulates the conditions of the criterion movement as closely as possible.

Recent models dealing with strategies for closed-skill preparation (e.g., Boutcher & Rotella, 1987; Singer, 1986) emphasize the importance of creating a positive feeling state about the movement that is about to be performed. In particular, Boutcher and Rotella (1987) recommend a “kinesthetic coupling” (p. 134) of the look and feel of the upcoming movement. One explanation, then, for the superiority of practice swings in the present study is that, among other things, it may have energized the sensation associated with effective serve performance. It is also possible that this activity facilitated the adjustment of a greater number of support systems comprising the activity set (Nacson & Schmidt, 1971) for the serve. For example, taking practice swings produced restorations (i.e., increases) in somatic arousal and positive cognitive arousal, which likely contributed to the reinstatement of appropriate (i.e., prerest levels) of physiological and psychological activation. It is also possible that subjects taking practice swings may have engaged in some incidental imagery, although this appears less likely given the brief time (i.e., 5 s) between practice attempts.

Of the remaining warm-up activities, striking and catching the ball seemed to exert the most influence on postrest performance, suggesting that hand–eye coordination may be one support system of the activity set for serving. Running in place successfully restored prerest levels of somatic arousal but had only a modest influence on postrest performance accuracy. This result conflicts with the findings of earlier research in which somatically arousing activity was found to eliminate WUD in gymnastics vaulting (Anshel, 1985), thereby suggesting that the performance of some skills may be more dependent on the maintenance of somatic arousal levels than is that of others (see Martens & Landers, 1970, for a discussion). Although somatic arousal was found to be the best predictor (of the three arousal measures) of immediate postrest performance accuracy, it appears that a warm-up designed solely to increase somatic arousal levels (e.g., running in place) does not always guarantee reductions in postrest WUD.

Least effective of the warm-up activities was the imaging of successful
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execution of the task. That an imagery warm-up failed to diminish WUD is consistent with the results of Anshel (1985), who found no influence of imaging on postrest WUD for the handspring vault. However, the present findings conflict with those of Ainscobe and Hardy (1987) and Anshel and Wrisberg (1988) who reported reductions in WUD following positive imaging of double leg circling on the pommel horse and baseball batting, respectively. The inconsistency of results across these studies may be due to differences in the imagery ability of subjects. Although all of the subjects in the mental imagery group in the present study indicated that they (a) regularly incorporated imagery in their training, (b) complied with imagery instructions, and (c) were able to produce relatively vivid images during their warm up, no measure of imagery ability was obtained. Unfortunately, this seems to be the case in most investigations examining the role of imagery in reducing WUD.

Recent research by Goss, Hall, Buckolz, and Fishburne (1986) suggests that the imagery ability of subjects should not be taken for granted. In that study, it was discovered that mental rehearsal of a movement was more advantageous for individuals who had high levels of imagery ability than for those with low imaging ability. Thus, to more accurately determine the relative efficacy of imagery as a warm-up activity, future research should include assessments of the imagery ability or imagery experience of subjects (see Smith, 1987, for a review of sport imagery issues).

Except for the findings that heart rate declined more for control and imagery subjects over 15 min of rest than over 5 min and that the performance accuracy of the imagery group was lower after the longer rest interval than after the shorter one, rest interval length did not appear to have much influence on the results of the present investigation. This finding is consistent with the results of Wrisberg and Anshel (1993) who compared 5- and 15-min intervals in an investigation of WUD in the performance of tennis groundstrokes. In other previous research, the existence of WUD has been demonstrated after rest periods as short as 10 min and as long as 20 min (Ainscobe & Hardy, 1987; Anshel, 1985; Anshel & Wrisberg, 1988; Nacson & Schmidt, 1971; Schmidt & Nacson, 1971; Schmidt & Wrisberg, 1971). Anshel and Wrisberg (1988) reported postrest performance decrements after both a 15-min rest and a 6-month lay-off. However, in the latter instance, it was concluded that the decrement in performance was due to losses in memory strength rather than to the insufficient adjustment of support systems. Taken together, then, the available evidence suggests that WUD may be evidenced after as little as 5 min of rest and as much as 20 min, although the minimum and maximum duration of rest intervals that produces WUD remains to be determined.

In summary, the results of the present study suggest that an effective warm-up for the tennis serve should include rehearsal of the mechanical properties of the criterion task. However, it must also be noted that all four warm-up activities (when compared to the control condition) produced significant increases in somatic arousal and positive cognitive arousal, significant decreases in negative cognitive arousal, and significantly higher immediate postrest performance. Therefore, it appears that support systems (Nacson & Schmidt, 1971) for the tennis serve may also include hand–eye coordination, arousal level, and, to a lesser extent, mental imagery. Finally, it is acknowledged that, although the warm-up tasks used in the present study were chosen because they could be
performed by tennis players in applied settings, it remains to be determined whether such activities, alone or in combination, reduce postrest WUD (e.g., following a change of sides) during actual competition.

References


**Notes**

1It is also possible that imagery serves to strengthen the memory properties of a criterion task rather than to adjust support systems. However, for accomplished performers who are presumably close to maximum memory strength levels, it is less likely that imagery would contribute additional increments of learning to the criterion task.

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