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[Original Article]

Changes of Heart Rate, Somatic Anxiety, and Performance of Japanese Archers during Practices and Matches

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ABSTRACT

This field study examined the changes of the psychological and physiological responses and performances of competitive archers during practices and actual matches. Five undergraduate Japanese archers participated in the free preparatory practices, the two- or three-round formal practices and the five-round matches. Subjects rated their somatic anxiety after each round of formal practice and match during which their heart rates were recorded continuously. Hitting performance data were obtained from practices' and matches' results. Results were analyzed using the intraindividual analysis which revealed that heart rates were remarkably elevated during matches and that the subjects showed higher somatic anxiety scores during matches than practices. Heart rate and somatic anxiety are moderately related to one another. There are curvilinear relationships between heart rate (somatic anxiety) and performance. The results and implications were discussed in the light of the multidimensional anxiety and the inverted-U relationship between anxiety and performance.

Key words: arousal, heart rate, anxiety, stress, sport, stage fright, case study

Many athletes failed to perform up to their potential because they were unable to maintain their concentration in front of an audience and were not able to cope with the pressure of competition. This reaction is not of course limited to athletics. It is found in a variety of situations, including public speaking and pressure resulting due to examinations.

Gould, Horn, & Spreeman (1983) reported that even elite wrestlers were anxious or worried in 66 per cent of their matches. Thus, the sports' environment provides a natural laboratory in which to study arousal-related behavior.

The concept of arousal, which is often used interchangeably with other terms such as drive, tension, and activation, refers to the degree of energy

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released by the organism. This varies on a continuum from deep sleep to high excitement (Duffy, 1957).

The relation between arousal and motor performance has received considerable attention in psychological literature. The two main hypotheses regarding this relationship are drive theory (Hull, 1943: Spence & Spence, 1966) and the inverted-U hypothesis (Yerkes & Dodson, 1908). Drive theory proposed a positive, linear relationsip between arousal and performance on the well-learned task. However, a large number of studies that tested drive theory failed to support the theory's predictions. Contrary to predictions, many athletes reported that their performances were disrupted by excessive arousal.

In place of drive theory, the inverted-U theory has emerged as the favored hypothesis of the relation between arousal and motor performance (Duffy, 1957, 1962; Landers, 1980: Oxendine, 1970). The theory asserts a curvilinear relationship such that increases in arousal are associated with improvements in motor performance until an optimal level is reached; further increases then lead to decrements in performance. Past researches supported the inverted-U hypothesis (Burton, 1988; Sonstroem & Bernardo, 1982; Weinberg & Genuchi, 1980). Osato (1979, 1983, 1988) reported a rather extensive series of experiments and demonstrated the hypothesis using various competitive situations. After reviewing inverted-U hypothesis literature, Neiss (1988) however, argued that the inverted-U hypothesis is supported only in weak and psychologically trivial fashion.

In studying anxiety responses especially in reaction to threatening situations, such as sport competition, numerous questions remain concerning the dynamics of competitive anxiety and its relationship to performance. For example, the low covariation reported in the majority of empirical researches was the same between psychological and physiological indices. Another example is that successful athletes tended to use their anxiety as a stimulant for better performance, while less successful athletes seemed to arouse themselves to a near panic state by self-doubting verbalization and images of failure.

Recently, in an effort to develop more reliable and valid measurements of anxiety, some psychologists have come to view anxiety as a complex multidimentional construct which can be separated into two components, namely: cognitive and somatic anxiety (Gould, Petlichkoff & Weinberg, 1984; Jones & Hardy, 1990). Cognitive anxiety is characterized by worry, negative expectations, cognitive concerns about oneself, lack of concentration, and images of failure. On the other hand, somatic anxiety refers to the perception of physiological-affective symptoms of the anxiety experience such as rapid heart rate, shortness of breath, sweaty hands, nervousness, and tension. The somatic anxiety represents the perceived affective-autonomic responses of an individual rather than the actual physiological reactions per se.

Morris and Liebert (1969) hypothesized that whereas the cognitive component of anxiety interfers with cognitive performance, somatic anxiety may be the component which interferes with motor performance. In sports, somatic anxiety may influence performance more directly because the physical demands of the task often necessitate the attainment of an optimal physiological state of readiness for the best possible performance.

The purpose of the present investigation is to examine the relationship between heart rate, somatic anxiety, and performance in competitive Japanese archers during three different kinds of practices as well as the actual matches.

The richness of field setting is important when one is interested in increasing the potency of an independent variable. This is particularly relevant for testing the arousal-motor performance relationship because higher levels of arousal can be obtained when one is placed in a situation which is ego-involving, important, and evaluative.

This is the reason why we focused on the Japanese archery as the task because shooting the target using the traditional Japanese techniques

requires fine psycho-muscular control. It would be particularly sensitive to changes in psychological arousal and in social settings.

It is also worth considering the appropriateness of the statistical analyses. Parfitt, Jones, and Hardy (1990) argued that, rather than conducting between-subjects analyses of relative performance levels, one should consider within-subject analyses of actual performance levels. For, it is the effect of changing anxiety levels upon an individual's actual performance that is important and not how scores vary between individuals with different anxiety levels. Accordingly, within-subject analyses of dependent measures were adopted in this study. In the present study, the physiological measure examined was heart rate. This measure was chosen because it has been used in a number of studies as a physiologocal indicator of anxiety (Hardy & Whitehead, 1984; Idzikowski & Baddeley, 1983; Ussher & Hardy, 1986).

METHOD

Subjects. The subjects were 3 female (designated as F89OT, F91OR, and F91KM) and 2 male (designated as M90TK and M90NS) Japanese archers enrolled in the Gifu University Japanese Archery Club ranging in age from 19 to 21. They were players of different league matches. Their probabilities of hitting the target (and number of shooting trails) for the last 5 days of their match were 0.528 (n = 144) for Subject F89OT, 0.581 (n = 136) for Subject M90TK, 0.464 (n = 192) for Subject F91OR, 0.594 (n = 160) for Subject F91KM, and 0.593 (n = 140) for Subject M90NS.

Matches. There were five formal matches held on different days at the Japanese archery stadium of Gifu University. The female team of three archers, in which subject F89OT played with, competed against the Nagoya University Japanese Archery Club and lost the game with a score of 36–38. The male team of eight archers, in which subject M90TK played with, competed against the Nagoya-Shioka University Japanese Archery Club and won the game with a score of 100–81. The female team, in which subject F91OR played with, competed against the Shizuoka University Japanese Archery Club and won the game with a score of 38–31. The female team, in which subject F91KM played with, competed against the Chukyo-Woman University Japanese Archery Club and won the game with a score of 44–43. Lastly, the male team, in which subject M90NS played with, competed against the Aichi-Kogyo University Japanese Archery Club and lost the game with a score of 103–119. He was relieved of his role because of his poor performance during the match.

Shooting Performance Assessment. Subjects were required to shoot the target from a distance of 28 meters. The target was a white concentric circle, 36 centimeters in diameter with a 12-centimerter bull's-eye. If archers hit the target with the arrows, their team received 1 score.

Heart Rates. Heart rates were continuously recorded every five seconds by the PE3000 system (made in Finland) during the three different kinds of practices and matches.

Somatic Anxiety. Subjects were asked to rate their own feeling after the each round of the formal practice and match. Somatic anxiety items included 'My heart was racing', 'I felt tense', 'My knees were trembling', 'I was upset', and 'I got stage fright'. Responses to each item were on a Likert scale ranging from 1 (not at all) to 4 (very much so). Thus, possible scores ranged from 5 to 20.

Procedure. Upon entering the Japanese archery stadium each subject was fitted with the heart rate recording equipment. Before the visiting team arrived at the stadium, the archers of the home team to which the subjects belonged had two kinds of practice sessions (the free and the formal). In the free practices, the archers shot arrows freely and their results were not recorded. The formal practices were carried out on the assumption of an actual match and their results were recorded in their notebooks. After these prepatory activities, they had free practices concurrently with the visiting team. Practice sessions were immediately followed by matches. The matches had five rounds.

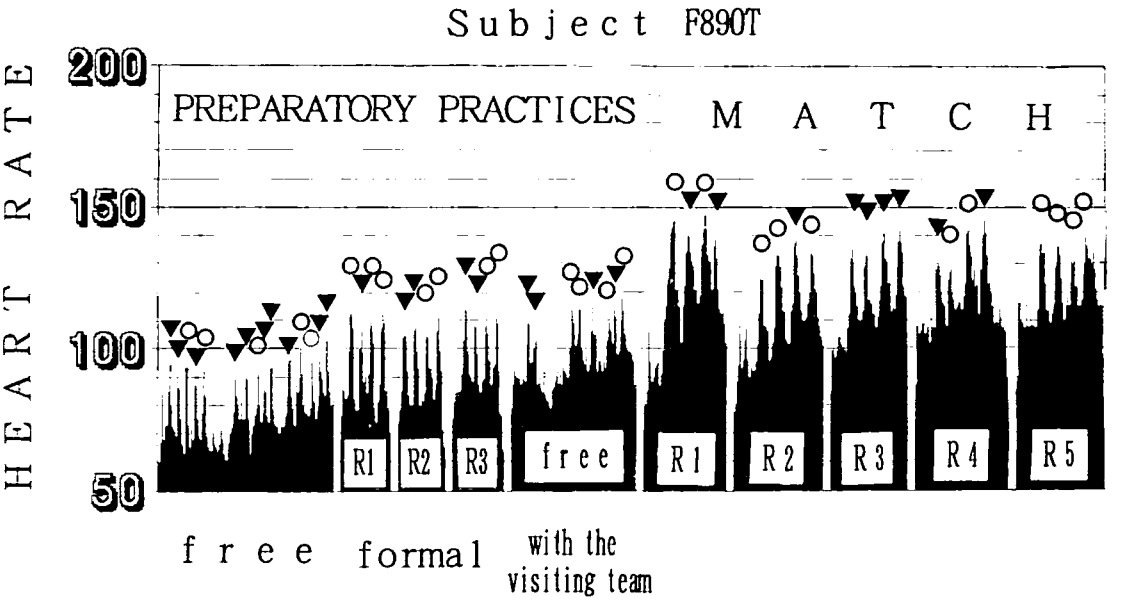

Fig. 1 Changes of heart rate and the shooting performance during the three kinds of practices and the match for Subject F89OT. The open circles and the filled triangles represent the subject's hits and misses on the target, respectively.

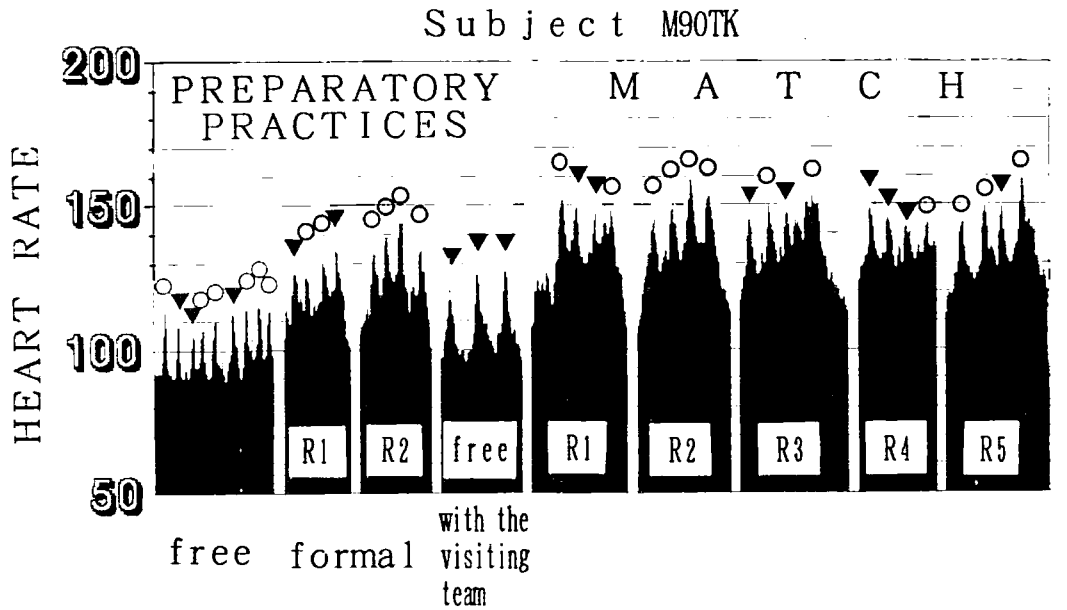

Fig. 2 Changes of heart rate and the shooting performance during the three kinds of practices and the match for Subject M90TK. The open circles and the filled triangles represent the subject's hits and misses on the target, respectively.

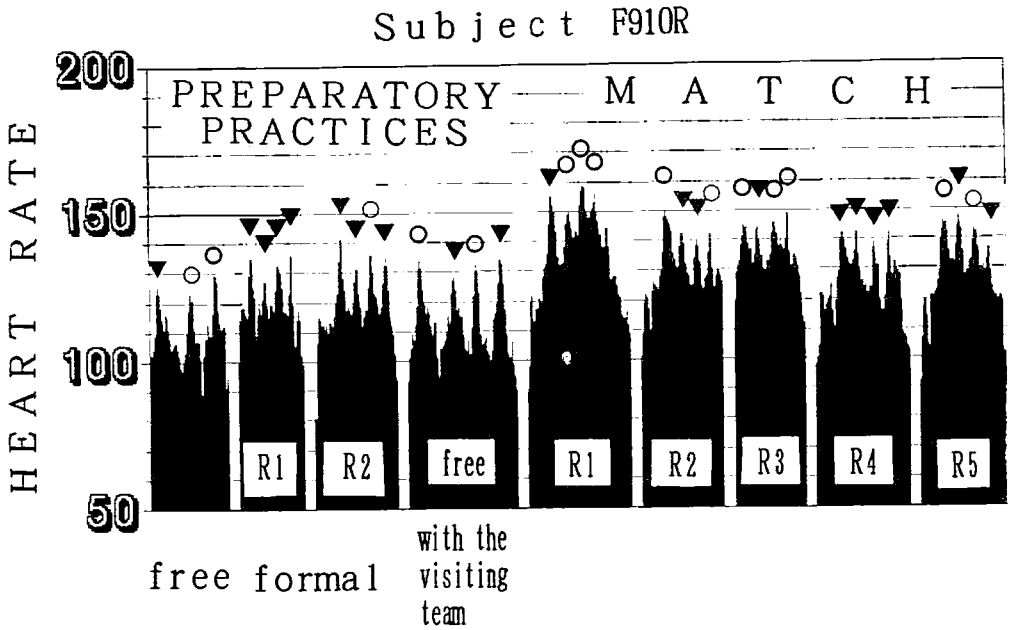

Fig. 3 Changes of heart rate and the shooting performance during the three kinds of practices and the match for Subject F91OR. The open circles and the filled triangles represent the subject's hits and misses on the target, respectively.

The archers had 4 shooting trials in each round. The spectators cheered their own teams and never hooted at the opposite teams during the practices and the matches.

RESULTS

Heart Rate

Heart rates increased at each shooting motion and then decreased after the motion (Fig. 1 through Fig. 5). Each "heart rate" wave corresponded exactly to each shooting trial and the peak appeared about 10 sec. after releasing the arrow.

Subject F890T. A one-way analysis of variance was employed to analyze the means of the maximum heart rates of each trial for the three kinds of practices and that of the match. Results (Fig. 1) revealed a significant main effect, $F(3/51) = 254.09$, $p < .001$. The least significant difference (LSD) post hoc tests indicated that means were low during the free preparatory practice ($m = 93.1$), medium during the formal preparatory practice ($m = 110.1$) and during the free practices with the visiting team ($m = 113.8$), and high during the match ($m = 137.5$).

Subject M90TK. A one-way analysis of variance was employed to analyze the means of the maximum heart rates of each trial for the three kinds of practices and that of the match. Results (Fig. 2) revealed a significant main effect. $F(3/39) = 162.20$, $p < .001$. The LSD post hoc tests indicated that means were lowest during the free preparatory practice ($m = 110.9$), low during the free practice with the visiting team ($m = 124.7$), medium during the formal preparatory practice ($m = 134.5$), and high during the match ($m = 149.0$).

Subject F91OR. A one-way analysis of variance was employed to analyze the means of the maximum heart rates of each trial for the three kinds of practices and that of the match. Results (Fig. 3) revealed a siginificant main effect, $F(3/32) = 22.45$, $p < .001$. The LSD post hoc tests indicated that means were low during the

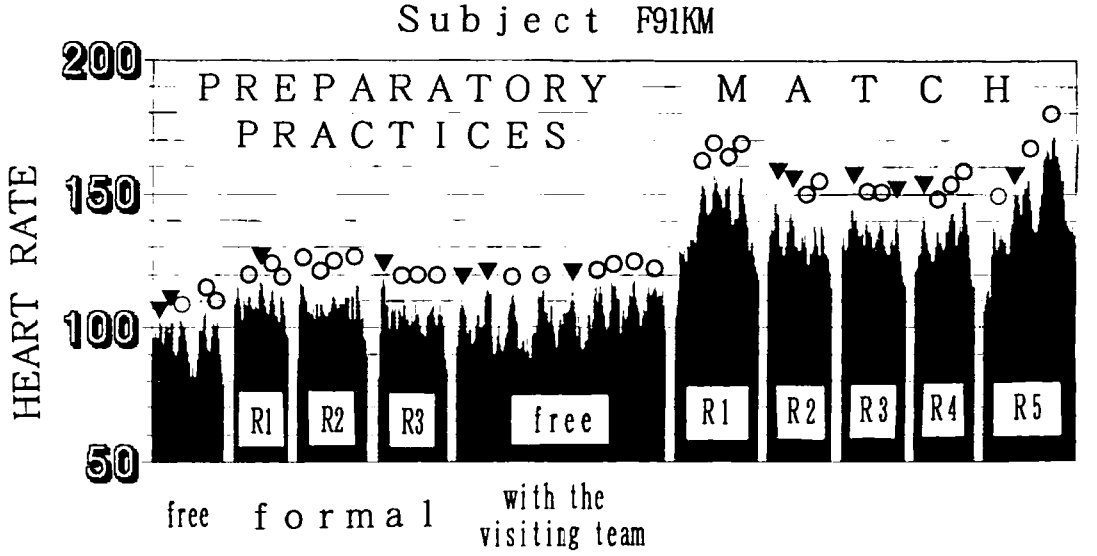

Fig. 4 Changes of heart rate and the shooting performance during the three kinds of practices and the match for Subject F91KM. The open circles and the filled triangles represent the subject's hits and misses on the target, respectively.

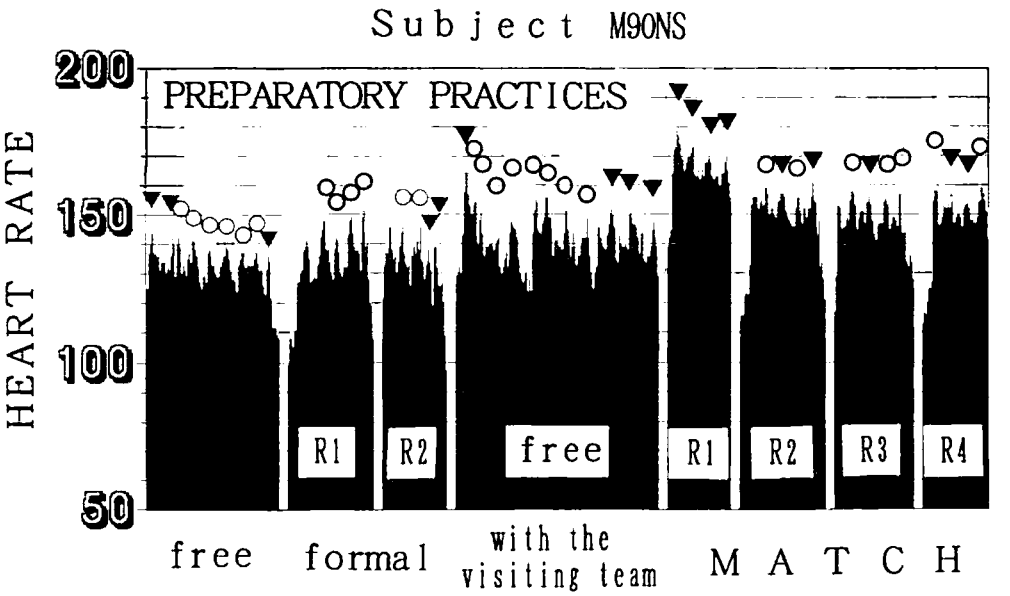

Fig. 5 Changes of heart rate and the shooting performance during the three kinds of practices and the match for Subject M90NS. The open circles and the filled triangles represent the subject's hits and misses on the target, respectively.

free preparatory practice (m = 125.7), during the free practice with the visiting team (m = 132.0) and during the formal preparatory practice (m = 134.3), and high during the match (m = 145.7).

Subject F91KM. A one-way analysis of variance was employed to analize the means of the maximum heart rates of each trial for the three kinds of practices and that of the match. Results (Fig. 4) revealed a siginificant main effect, $F(3/42) = 113.34$, $p < .001$. The LSD post hoc tests indicated that means were low during the free preparatory practice (m = 103.0), medium during the formal preparatory practice (m = 111.3) and during the free practice with the visiting team (m = 114.6), and high during the match (m = 146.5).

Subject M90NS. A one-way analysis of variance was employed to analyze the means of the maximum heart rates of each for the three kinds of practices and that of the match. Results (Fig. 5) revealed a significant main effect, $F(3/41) = 35.39$, $p < .001$. The LSD post hoc tests indicated that means were lowest during the free preparatory practice (m = 139.6), low during the formal preparatory practice (m = 145.9), medium during the free practice with the visiting team (m = 152.5), and high during the match (m = 161.7).

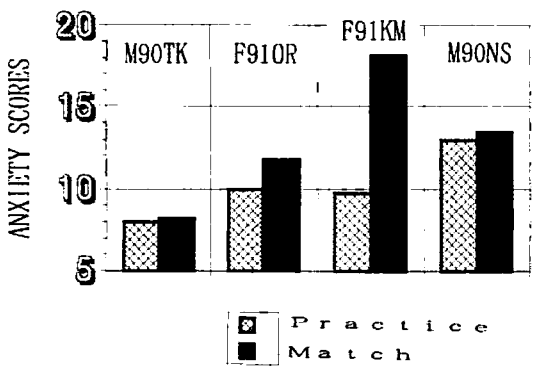

Fig. 6 The mean somatic anxiety scores for each subject during the practices and their individual match. Subject F89OT, who failed to fill out the forms during the preparatory formal practices, was excluded from the analysis.

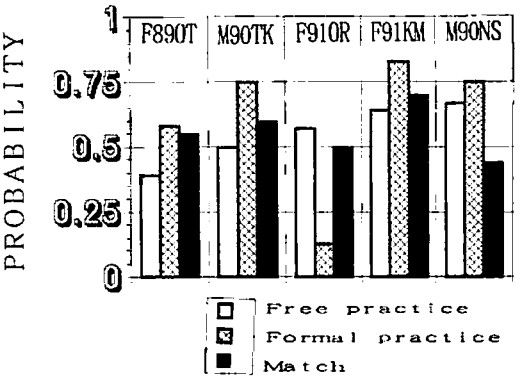

Fig. 7 The probability of hitting the target during the free and the formal practices and in the individual matches.

Somatic Anxiety

All subjects except for Subject M90TK showed high somatic anxiety scores during the first rounds of the matches. Subject F91KM and Subject M90NS showed full somatic anxiety scores during the first and during the last rounds of the matches respectively. A 2 (practice vs. match) × 4 (archers) repeated-measures ANOVA for unweighted means revealed a significant main effect, $F(1/22) = 11.76$, $p < .01$. Fig. 6 illustrates all 4 archers, especially Subject F91KM, showed higher scores during the matches than during the practices.

Subject F89OT who failed to fill out the forms during the preparatory formal practices was excluded from the analysis.

Performance

The probability of hitting the target was the rate of hits over the shooting trials. Fig. 7 illustrates all subjects, except for F91OR, who performed their best during the preparatory formal practices. However, the one-way analysis of variance was not significant ($F < 1$). This implies that there was no statistical difference between performance measures. All subjects except for M90NS showed the same performance level during the matches as well as during the practices of the last five days. A 2 (last 5 days vs. match) ×

Table 1
Intercorrelations among heart rate (HR), somatic anxiety and performance (hitting probability) for each subject and the total sample

Subject	HR and Anxiety	Anxiety and Performance	Performance and HR
F89OT (8)	.591	.021	−.367
M90TK (5)	.194	−.222	−.130
F91OR (7)	.470	−.241	.653
F91KM (9)	.945**	−.349	−.092
M90NS (6)	.630	−.606	−.744
Total (35)	.388*	−.082	−.142

Note. ( )=N. of data $^{*}p < .05$ $^{**}p < .01$

5 (archers) analysis of variance revealed no significant main effect. $F(1/4) < 1$.

Correlations among Measures

Peason product-moment correlations were conducted to examine the interrelationships among heart rate, somatic anxiety, and performance. Results revealed only a significant positive correlation between heart rate and somatic anxiety (Table 1). The results supported the hypothesis that the physiological and psychological measures of anxiety were related. However, the measures were only moderately related to one another.

DISCUSSION

One particularly noteworthy finding is that the competitive matches were a realistic threat sufficiently stressful to produce remarkable increases in physiological (HR) and psychological (somatic anxiety) arousal. The archers used the same shooting motions following traditional Japanese techniques during the practices and the matches. However, for most subjects, heart rates elevated to 150 bpm during the first rounds of the matches. Subject M90NS (Fig. 5 and 6) especially showed an high arousal not only during the match but also during the preparatory practices and did not perform well in the match (Fig. 7). It is reasonable to assume that he was in a state of 'stage fright' even prior to competition.

In line with the results of other researchers (Fenz & Epstein, 1967; Fenz & Jones, 1972; Hammerton & Tickner, 1968; Johnson, 1980; Karteroliotis & Gill, 1987; Powell & Verner, 1982) the physiological measure (HR) significantly increased from precompetition to midcompetition.

The researchers (Martens et al., 1990; Karteroliotis & Gill, 1987) proposed that somatic anxiety increases prior to competition and peaks at the beginning of competition, and that somatic anxiety and physiological arousal should not be interpreted as the same response. In contrast to their proposal, somatic anxiety significantly increased during practices and throughout the matches. Somatic anxiety showed its peak at the first or at the last rounds of the matches and continued over the course of the competition. The results of this investigation are consistent with Caruso et al. (1990) and Parfitt & Hardy (1987).

A possible explanation for the remarkable increases of heart rate and somatic anxiety from pre- to midcompetition is that the subjects are highly ego-involved in their task and the game's win-loss result had significantly influenced their physiological and psychological arousal. Therefore, somatic anxiety and heart rate should be related to each other only in highly competitive situations.

It is important to remember that the increases in physiological state anxiety in this experimental study may not represent true anxiety. Perhaps competitive settings with clearer real threats might have induced stronger anxiety responses and different relationships than the ones observed in the laboratory setting. Thus, more caution must be exercised in interpreting 'anxiety' in these types of investigations.

Previous researches found an inverted-U relationship between somatic anxiety and swimmers' performance time (Burton, 1988), between somatic anxiety and pistol shooting performance (Gould et al., 1987), and between somatic anxiety and basketball performance (Sonstroem & Bernardo, 1982).

In line with these studies, the pattern of re-

sults of this study suggested the inverted-U relationship between heart rate and hitting probability performance is also quite similar to the figure reported by Miyamoto (1992). Sonstroem & Bernardo (1982) argued that the intrasubject data appeared to be remarkably consistent in supporting the inverted-U curve hypothesis.

However, it is noticeable that four of five subjects in the present study did not deteriorate but increased their performance not only during formal practices but also during matches compared to their data of the last five days. Subject M90NS was the only archer who showed inferior performance to during his last five days.

Nevertheless, current data are insufficient to draw conclusions, and further field research should be encouraged to use the intrasubject comparisons.

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