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ORIGINAL RESEARCH

Heart Rate Variability Flow and Emotional Intelligence as Predictors of Novice Archers' Shooting Accuracy

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Abstract

We examined whether Heart Rate Variability (HRV), together with flow and trait emotional intelligence may predict variations in arrow shooting accuracy for novice archers. 30 novice archers ranging in age from 18 to 23 volunteered. Participants first completed the Schutte Emotional Intelligence Inventory. Then, participants' resting HRV was measured for 4 minutes. Afterwards, participants shot 10 arrows from 18 m to an 80 cm diameter target while their HRV was measured. Accuracy was determined in terms of radial distance (error) from the center of the target. In order to calculate an overall performance score, the median value of the 10 arrows was calculated for each participant. Results showed that HRV, certain flow dimensions, and trait emotional intelligence may have account for variations in novice archers' shooting accuracy. On the basis of the results obtained from the current study, we conclude that the determination of performance or shooting accuracy should be based on both physiological and psychological characteristics, in this case, HRV, flow, and emotional intelligence. This information might be beneficial for coaches, athletes, or other practitioners aiming to develop archers' performance.

Keyword: HRV, low to high frequency ratio, flow, emotional intelligence, archery.

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INTRODUCTION

In a psychomotor task in which performance is determined by the degree of precision, such as archery, psychological and physiological factors may collectively influence performance. Archery is one of the unique athletic disciplines requiring a high level of precision, which is closely related to individual differences in physiological activity and psychological characteristics. Therefore, determination of performance in archery should be based upon both physiological and psychological parameters.

In the present study, we recognized HRV as a physiological antecedent of performance in archery, which is an important marker of autonomic nervous system (ANS) activity modulation (Luft, Takase, & Darby, 2009). The ANS is modulated by two different well-balanced systems: the sympathetic nervous system (SNS), which is related to the fight or flight response; and the parasympathetic nervous system (PNS), which is associated with rest and the digestive system (Thayer & Lane, 2009). According to Massimo Pagani's HRV model (Malliani, Pagani, Lombardi, & Cerutti, 1991; Montano et al., 2009; Pagani et al., 1986), three components represent SNS, PNS, and the balance between SNS and PNS. Thus, high frequency (HF) power (0.15 to 0.40 Hz) is recognized as an indicator of cardiac parasympathetic tone. On the other hand, low frequency (LF) power (0.04 to 0.15) is accepted as a marker of cardiac sympathetic outflow. Sympathovagal tone is determined by the low to high frequency ratio (LF/HF) (Reyes del Paso, Langewitz, Mulder, van Roon, & Duschek, 2013). As HRV is recognized as a parameter with the potential to reflect attentional workload during sport (Abernethy, B., Maxwell, J. P., Masters, R. S., van der Kamp, J., & Jackson, 2007), it is of great importance to determine the role of HRV in archery performance. Despite a lack of evidence supporting the link between HRV and archery performance, previous results from other fields of psychology demonstrating the association between HRV and mental or attentional workload (Hansen, Johnsen, & Thayer, 2003) provide a theoretically sound basis to assume that HRV may potentially account for variations in archery performance, requiring high levels of mental and physical precision.

Another factor thought to be an antecedent of performance in archery is the experience of flow. The underlying logic for the study of flow experience in relation to archery performance is the fact that defining features of flow, such as reduced mental effort (Koehn, Morris, & Watt, 2013), total immersion in an activity (Bakker, 2008; Fullagar & Kelloway, 2009), and high concentration (Ullén et al., 2012), may lead to higher precision in archery. Another reason to study flow in relation to performance is the lack of research findings clarifying the flow-performance relationship. Previously, researchers have focused largely on factors affecting flow experience (Kaufman, Glass, & Arnkoff, 2009; Elbe, Strahler, Krustrup, Wikman, & Stelter, 2010). Thus, the issue of whether flow facilitates performance in an activity requiring an extreme level of concentration and precision remains unclear and deserves a careful examination in well-controlled experiments. Further, in the field of sport psychology, researchers have focused mainly on negative emotions as predictors of performance and simply ignored examining whether there is a relationship between positive emotions and performance. Therefore, there is a clear need to understand the link between performance in archery and flow, which represents positive emotional states associated with better performance.

Trait emotional intelligence might be another psychological individual difference that can lead to better athletic performance. "Trait emotional intelligence (or 'emotional self-efficacy') refers to a constellation of behavioral dispositions and self-perceptions concerning one's ability to recognize, process, and utilize emotion-laden information" (Petrides, Frederickson, & Furnham, 2004, p. 278), and overlaps considerably with emotional skills thought to lead to better athletic performance, such as establishing and maintaining appropriate emotional conditions (Robazza, Bortoli, & Nougier, 2000). Moreover, previous research has shown that trait emotional intelligence is associated with athletes' HRV responses to mental stressors (Laborde, Brüll, Weber, & Anders, 2011), muscular performance under stress (Tok, Binboğa, Guven, Çatikkas, & Dane, 2013), and psychological skill use (Lane, Thelwell, Lowther, & Devonport, 2009). Therefore, there are theoretical reasons to suggest that trait emotional intelligence may be a psychological construct with the potential to explain variations in archery performance.

In the present study, we aimed to examine whether HRV, together with flow and emotional intelligence, may predict variations in archery performance. Such a multi-dimensional approach using techniques from different scientific branches may lead to a better understanding of the factors affecting performance in archery, which requires high levels of precision and concentration. In our study, the LF/HF ratio, as an indicator of stress, was expected to increase from baseline in the arrow shooting session due to the muscular, cognitive, and respiratory demands of archery. Moreover, we predicted that archers' performance would be associated with higher LF/HF ratios. Considering the requirements of better performance in archery, such as low psycho-physiological arousal, our prediction regarding the LF/HF ratio and shooting performance may seem contradictory. However, our sample consisted of novice archers, thus, the application of proper shooting techniques that require high levels of muscular and mental effort should lead to an increase in the LF/HF ratio. We also expected that flow and emotional intelligence, which may facilitate appropriate emotional conditions, should be related to better performance in archery.

METHOD

The Population and the Sample

Participants were 30 college students ranging in age from 18 to 23. None of the participants had previous experience in archery. However, they enrolled in an archery class to receive course credit. At the end of the 14-week course, individuals having a final exam grade higher than 70 were invited to take part in the study. Participants had no acute or chronic neuromuscular disease or psychiatric disorder and were required to abstain from the use of any medications that may affect nervous system functioning.

Data Collection Tool

In this study, two different measurement tools were adopted. These tools were "The State Flow Scale" and "The Schutte Emotional Intelligence Scale".

The State Flow Scale: The State Flow Scale, developed by Jackson and Eklund (2002) and adapted into Turkish by Aşçı, Çağlar, Eklund, Altıntaş, and Jackson (2007), was used to measure participants' flow experiences. The scale features 36 items that require a response using a five-point Likert-type scale. The State Flow Scale measures nine theorized dimensions of flow: challenge-skill balance, action-awareness merging, clear goals, unambiguous feedback, concentration on the task at hand, sense of control, loss of self-consciousness, time transformation, and autotelic experience.

The Schutte Emotional Intelligence Scale: The Schutte Emotional Intelligence Scale, developed by Schutte et al. (1998), revised by Austin, Saklofske, Huang, and McKenney

(2004), and adapted for the Turkish population by Tatar, Tok, and Saltukoglu (2011), was used to measure emotional intelligence. The scale contains 41 items and generates an overall EI score, as well as scores for three subscales: regulation of emotion, appraisal of emotion, and utilization of emotion. Regulation of emotion measures the extent to which people report being able to control their own and others' emotions; utilization of emotion measures the extent to which people report being able to use emotions in solving problems; and appraisal of emotions measures the extent to which people report being able to identify their own and others' emotions. Austin et al. (2004) provided evidence for the construct validity of the first two factors and the full scale's internal reliability.

Procedure

In the first stage of the experiment, participants first completed the Schutte Emotional Intelligence Inventory. Then, their resting HRV was measured for 4 minutes while sitting. In the next stage, participants shot 10 arrows in 4 minutes from 18 m to an 80-cm diameter target. The shooting task was self-paced, so participants decided when to shoot an arrow and how long to prepare to shoot. Based on a pilot study of five novice archers, we determined that participants were required to shoot an arrow in approximately 20–25 seconds. Participants were given additional arrows if they finished their shooting in less than 4 minutes. However, only the first 10 shots were taken into account. Lastly, participants completed the State Flow Scale. Performance was determined as the radial distance (error) from the center of the target, which was considered a measure of "accuracy"–the smaller the distance, the greater the accuracy. In order to calculate an overall performance score, the median value of the radial distance to the center was taken into account for each participant. All experimental procedures were approved by the local ethics committee and all data were collected in accordance with latest version of the Helsinki Declaration. All participants completed a form providing informed consent, as approved by the ethics committee.

Data Analysis

To explore whether the LF/HF ratio differed between a resting state and during the shooting session, a Wilcoxon sign rank test was conducted. In order to examine the relationships between shooting accuracy and the LF/HF ratio recorded during arrow shooting, flow, and emotional intelligence, Spearman correlation coefficients were calculated. Lastly, stepwise regression analyses were carried out to determine whether predictor variables, LF/HF ratio, flow, and emotional intelligence, could predict significant amounts of variance in shooting accuracy.

FINDINGS

A Wilcoxon sign rank test showed that the LF/HF ratio differed significantly between resting (Mean Rank = 3.35) and during the shooting session (Mean Rank = 5.95, $z = 3.24$, $p = .001$). Spearman correlation coefficients were calculated to examine whether the LF/HF ratio, flow, and the trait emotional intelligence dimensions, as well as participants' overall scores were related to shooting accuracy (see Table 1). Among the emotional intelligence dimensions, only regulation of emotions ($r = -.40$, $p = .029$), appraisal of emotions ($r = -.38$, $p = .038$), and overall emotional intelligence ($r = -.54$, $p = .002$) scores were significantly related to shooting accuracy. The challenge-skill balance ($r = -.42$, $p = .023$) and clear goals ($r = -.44$, $p = .016$) dimensions of the flow scale were also significantly associated with shooting accuracy. Moreover, the LF/HF ratio was significantly correlated with shooting accuracy ($r = -.49$, $p = .006$).

Table 1. Relationship between HRV Trait Emotional Intelligence Flow and Shooting Accuracy

	Median	SD	Shooting Accuracy
LF/HF Ratio	6.27	3.5	**-.49****
Regulation of Emotions	48.03	5.49	**-.40***
Utilization of Emotions	21.03	3.78	-.29
Appraisal of Emotions	38.66	5.99	**-.38***
Challenge-Skill Balance	15.83	2.42	**-.42***
Action Awareness	12.93	4.20	.11
Clear Goals	17.43	2.26	**-.44***
Unambiguous Feedback	14.63	2.88	-.11
Total Concentration	16.56	1.75	-.14
Sense of Control	16.23	2.07	-.18
Loss of Self-Consciousness	14.43	3.87	.04
Transformation of Time	15.03	3.96	-.13
Autotelic Experience	18.46	1.79	-.21
EI Total	107.73	12.28	**-.54****
Flow Total	141.56	14.37	-.17

**$p < .01$; *$p < .05$

Based on the significant correlation coefficients observed in the former analyses we conducted a stepwise regression analyses to test whether the model consisting of LF/HF ratio; overall emotional intelligence score, as well as its regulation of emotions and appraisal of emotions dimensions; and the flow dimensions of challenge-skill balance and clear goals could significantly account for variations in archery performance. As can be seen in Table 2, in the resulting final model, only the LF/HF ratio, overall emotional intelligence score, and the challenge-skill balance dimension of flow were able to explain a significant amount of the variance in archery performance.

Table 2. Predictive Abilities of HRV Trait Emotional Intelligence and Flow for Shooting Accuracy

Independent variables	*B*	β	*t*	*r*	$_{Adj}R^2$
Constant	44.43		6.20	.669	.38
LF/HF ratio	-.523	-.358	-2.39		
Challenge-skill balance	-.842	-.410	-2.62		
EI overall	-.116	-.279	-1.76		

DISCUSSION AND CONCLUSION

In the present study, we aimed to examine whether accuracy in arrow shooting may be predicted by HRV, flow, and emotional intelligence. As archery is a task that demands a high level of attention, we anticipated that the HRV parameters of the LF/HF ratio would be able to account for variations in arrow-shooting precision. Further, we also expected that flow and emotional intelligence could account for variations in arrow shooting accuracy, mainly due to the role of these two psychological qualities in creating appropriate emotional conditions for better performance.

As expected, the LF/HF ratio increased significantly from resting to shooting, which confirms arguments emphasizing the effect of mental or attentional load on HRV (Hansen et al., 2003). The data also confirmed our prediction regarding the relationship between the LF/HF ratio and shooting accuracy. The LF/HF ratio was inversely correlated to the median value of radial distances from the center of the target. In other words, the higher the LF/HF ratio, the greater the accuracy in arrow shooting. Only one previous study, by Carrillo, Christodoulou, Koutedakis, and Flouris, (2011), reported an association between the LF/HF ratio and archery performance, which confirms the results observed in the present study. The fact that a higher LF/HF ratio or a lower level of sympathovagal balance may facilitate shooting accuracy can be considered logical, demonstrating the effect of mental load on HRV. In this respect, former studies have consistently shown that psychological (Petrowski, Herold, Joraschky, Mück-Weymann, & Siepmann, 2010), mental (Luft et al., 2009), and attentional (Park, Vasey, Van Bavel, & Thayer, 2013) loads may have a robust effect on HRV and performance.

However, readers should take into account several important issues when interpreting our results. First, the sample of the present study consisted of novice archers, who invest more physical and mental effort than do experienced archers. Thus, the LF/HF ratio of experienced archers may be lower. Therefore, in future studies, the link between HRV and shooting accuracy in archers should be studied with both novice and experienced archers. Attempts by archers to control their respiration rate should also be considered in regards to the LF/HF ratio and shooting accuracy, since they may have a vital effect on HRV. In a recent study, Neumann and Thomas, (2009) observed an increase in LF activity in elite golfers, but not in novice golfers. The researchers argued that increase in LF activity should stem from respiration rate rather than from ANS activity. Thus, researchers aiming to understand the link between HRV and shooting accuracy should consider the effect of respiration rate on HRV.

Our results provided only partial support for the predictions regarding flow and arrow shooting accuracy. Among the flow dimensions, only the challenge-skill balance and clear goals dimensions were found to be associated with a higher level of shooting accuracy. However, only challenge-skill balance emerged as a significant predictor in the final regression model. Interestingly, researchers in the field of sport psychology have focused on factors affecting the flow state rather than the flow-performance relationship (Koehn et al., 2013; Swann, Keegan, Piggott, & Crust, 2012). Only a few studies have examined the effect of flow on performance in terms of winning or losing (Bakker, Oerlemans, Demerouti, Slot, & Ali, 2011; Koehn, & Morris, 2012). Further, no previous study has examined whether performance in archery might be related to flow. Challenge-skill balance, which is a defining feature of flow experience, involves a perceived high level of skill, the ability to act, or a capacity to meet challenges (Flett, 2015), which may possibly play an important role in creating appropriate emotional conditions for a better performance. Consequently, the present study provides evidence for the argument that flow, especially the challenge-skill balance dimension, may have the ability to facilitate performance in archery.

Trait emotional intelligence was also found to be a significant predictor of shooting accuracy, which signifies that individuals with higher overall emotional intelligence scores were more precise in arrow shooting. The effect of trait emotional intelligence on individuals' appraisals of stress may provide an explanation for the observed relationship between emotional intelligence and shooting accuracy. Previously, individuals with high trait emotional intelligence have demonstrated a greater tendency to appraise stress as a challenge rather than as stress (Matthews et al., 2006; Mikolajczak & Luminet, 2008). Taken together, it can be argued that individuals who have higher emotional intelligence scores perceive the physical and psychological stress induced by arrow shooting as a challenge, which may in turn cause more accurate shooting performance. In addition, in a previous study by Tok et al. (2013), trait emotional intelligence was found to be associated with better motor performance under stress.

On the basis of the results obtained from the current study, we conclude that the determination of performance or shooting accuracy should be based on both physiological and psychological characteristics, in this case, HRV, flow, and emotional intelligence. This information might be beneficial for coaches, athletes, or other practitioners aiming to develop archers' performance.

The present study includes several limitations. First, our sample consisted of only novice archers, which limits the generalizability of the results. The relationship between shooting accuracy and HRV may be different for experienced archers, who can execute the necessary psychomotor skills automatically. Moreover, it seems that the consideration of respiration activity may lead to a better understanding of the relationship between shooting accuracy and HRV.

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