Influence of Psychological Pressure on a Sprint Start

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Abstract: In this study, we examined the influence of psychological pressure on the psychological, physiological, and behavioral aspects as well as performance in a sprint start. Fourteen university sprinters performed six 20-m sprint trials; three trials each in non-pressure and pressure conditions. The pressure was induced by the instruction of a cash reward for better performance, the threat of having to repeat the experiment in the event of worse performance, and evaluation of the sprint movement by biomechanics researchers. The visual analog scale (VAS), heart rate (HR), kinematic variables, and 20-m time were measured. Data analyses showed that the VAS and HR increased mildly by the pressure instruction. Significant negative correlations were observed between changes in HR and 20-m time and between changes in the 20-m time and maximum angular velocity of the knee joint. A significant positive correlation was observed between changes in HR and the maximum angular velocity of the knee joint. These results indicate that changes in physiological arousal and movement velocity induced by mild psychological pressure played a significant role in the sprint performance.

Key words: inverted-U model, speed, strength

1. Introduction

Pressure is a significant psychological factor that influences the performance of motor skills. Pressure is defined as “any factor or combination of factors that increases the importance of performing well on a particular occasion” (Baumeister, 1984).

Previous studies that examined the influence of pressure on the psychological, physiological, and behavioral aspects of motor skills have addressed accuracy-demanding motor skills such as golf putting (Cooke, Kavussanu, McIntyre, & Ring, 2010; Tanaka & Sekiya, 2006, 2010, 2011), underhand ball-throwing (Higuchi, 2000), a cup and ball task (Tanaka, Urimoto, Murayama, & Sekiya, 2009), dart throwing (Murayama, Tanaka, Sugai, & Sekiya, 2007; Oudejans & Pijpers, 2010). These previous studies have shown that state anxiety measured as a psychological index and heart rate (HR) measured as a physiological index increased under pressure (e.g., Cooke et al., 2010). Movement speed and amplitude measured as behavioral indices have been reported to decrease under pressure (e.g., Tanaka & Sekiya, 2006, 2010).

Although the influence of pressure on accuracy-demanding motor skills has been studied in the studies mentioned above, little is known about the influence of pressure on motor skills that require strength and speed. Because the influence of pressure on motor skills that require accuracy as well as those that require strength and speed may differ, it is necessary to involve the latter kind of task for a full understanding of motor skills under pressure.

One of the motor skills that require strength and speed is a sprint start. Because a sprint start requires rapid acceleration from zero velocity at a ready position, it is considered to require strength and speed. Therefore, the first purpose of this study was to examine the influence of pressure on the psychological, physiological, behavioral aspects and performance of a sprint start.

It is also important to examine the relationships among the psychological, physiological, and behavioral aspects as well as the influence of pressure on each of these aspects. Hardy & Parfitt (1991) proposed the catastrophe model that predicts performance based on the relationship between cognitive anxiety and physiological arousal. The catastrophe model holds that, when a level of cognitive anxiety is low, the relationship between physiological arousal and performance forms into an inverted U shape. However, when a level of cognitive anxiety is high, reaching a certain level of physiological arousal leads to a drastic decline in performance. Furthermore, when a level of physiological arousal is low, the increment of cognitive anxiety leads to performance improvement. In contrast, when a level of physiological arousal is high, the increment of cognitive anxiety leads to performance decrement. These indicate that the performance outcome depends on the interaction between anxiety and physiological arousal. Pijpers, Oudejans, Holsheimer, & Bakker (2003) argued that the investigation of behavioral changes and their relationships with psychological and physiological changes is important for a full understanding of the mechanism of motor skills under pressure. However, the relationships among the changes in these factors and performance that consist of motor skills that require strength, power and speed were not addressed in the previous studies. Therefore, the secondary purpose of this study was to examine the relationship among the changes in psychology, physiology, behavior, and performance when an individual performs a sprint start under pressure.

2. Method

2.1. Participants

Fourteen undergraduate students (age 19.9± 1.5 years; 9 males and 5 females) who belonged to the short sprint section of track and field teams participated. Informed consent was obtained from all participants.

2.2. Task

The participants performed a 20-m sprint start with a starting block. Each participant was permitted to choose locations of starting blocks. Participants performed sprints in tight fitting clothing and track shoes.

2.3. Procedure

The experiment was conducted in an outdoor athletic field with an all-weather surface. Each participant completed his/her own individual warm-up for an hour before performing a 20-m sprint twice for practice. After the warm-up, measurement devices were attached. A transmitter for a heart rate (HR) monitor was attached to the participant's chest, and the experimenter held the receiver. Reflecting markers for movement analysis were attached to the top of the head, the acrominon (shoulder), lateral epicondyle of the ulna (elbow), midpoint between the styloid processes of the radius and ulna (wrist), great trochanter (hip), lateral condyle of the tibia (knee), lateral malleolus of tibia (ankle), calcaneus (heel), and fifth metatarsal (toe). With the exception of the head, the reflecting markers were placed on both sides of the body.

The following four instructions were given to the participants: (a) six sprints with maximal effort were should be performed; (b) in the first three trials, only the 20-m results would be measured; (c) participants should not push their chests forward at the finish; (d) when a participant jumps the gun, the trial is repeated. The participants then performed three non-pressure trials. Prior to each trial, cognitive anxiety was measured by using a visual analog scale (VAS). The VAS consisted of a 100-mm line on paper, and the participants were asked to draw a crossing mark between the left end, which corresponded with no anxiety, and the right end, which corresponded with maximal anxiety. Standard starting commands were used for each trial. A 10-min break was scheduled between trials.

Next, participants performed three pressure trials. Prior to the first pressure trial, the participants received instructions that were intended to produce pressure. They were told that they would receive a cash reward of 5,000 JPY if their average 20-m time was 0.06 s faster than the average time obtained in the non-pressure trials but would have to repeat the same experiment on another day if their average 20-m time was 0.06 s slower than the average time of the non-pressure trials. They were also told that the biomechanics researchers would evaluate and grade their movements. After the instructions were given, the VAS was determined for each participant before performing the first pressure trial. The VAS was also used immediately before the second and third pressure trials. Because the 10-min break between trials could have a detrimental effect on causing pressure, immediately before the second pressure trial, participants were informed that the results of their first trial had not been good. Furthermore, the participants were told that the experiment might have to be repeated. The participants were informed that, if they matched their best performance in the non-pressure trials, they could still receive the reward before the second pressure trial. Before the third pressure trial, they were told that their performance had improved, but success or failure was uncertain and that they had a chance to win the reward but also ran the risk to have to redo the experiment. All participants performed non-pressure trials before pressure trials because the average 20-m time of non-pressure trials had to be used in the script of pressure instruction.

After the participants finished the last trial, they were told that the instructions regarding the repetition of the experiment on another day and evaluations by biomechanics researchers were false.

2.4. Measures

As an index of performance, a digital high-speed camera (DKH B cam) was set to record movement at the finish line. On the opposite side of the lane, a pole was set vertically as a reference for the finish line. The camera recorded with a frequency of 100 Hz. The starter gun was fired in front of this camera to record the smoke. The 20-m time, which was defined as the interval between the gunshot and the time at which the participant passed the finish line, was used.

The VAS was used to measure cognitive anxiety. Reliability and validity of the VAS for the measurement of anxiety have been confirmed by Houtman & Bakker (1989). As an index of physiological arousal, HR was used. HR was measured using a HR monitor (Polar RE800CX) from the command, “on your mark,” to the gunshot in each trial. A video camera (Sony DCR-TRV70K) which was synchronized to the HR monitor was placed behind the starting blocks and used to identify the command and the gunshot. For behavior, the kinematics were measured. Two high-speed cameras (DKH B cam) were placed 4.95 m away from the center of the start line to record the video footages with the frequency of 100 Hz from the sagittal plane using a two-dimensional analysis (DKH Frame-DIAS for Windows). The placement of the starting blocks determined that of the front and rear blocks. In the kinematic analysis, a block start was split into two phases, the “setting phase” and “starting phase.” The setting phase was defined as a sequence of movement leading from the elevation of the hip to the start of head movement after the gunshot. The starting phase was defined as a sequence of movement leading from the start of head movement after the gunshot to removing the foot from the front of the starting block. Kinematics of these phases were analyzed because Coh, Jost, Skof, Tomazin, & Dolenec (1998) reported that kinematics in these phases correlated with the 20-m time.

In the setting phase, the angular displacements of shoulders, elbows, knees, and ankles were measured as indices of movement amplitudes. Negative values reflected flexion, and positive values reflected extension. In the starting phase, the angular displacements of shoulders, elbows, knees, and ankles were also measured. The maximal angular velocities of hip, knee, and ankle joints of the front leg were measured as indices of movement speed. In addition, as an index of the amplitude of the first step, a linear distance between take-off and landing positions of the rear leg was measured.

2.5. Statistics

The obtained values of all the variables were averaged across trials for each condition and for each participant. Because of the small sample size and the distribution patterns of the variables, nonparametric statistical models were applied. The Wilcoxon matched-pair signed-rank test was then used to assess the differences between the non-pressure and pressure conditions. For each variable and for each participant, we subtracted the mean value in the non-pressure condition from that in the pressure condition. This calculated value was defined as the amount of change by pressure. Spearman's rank correlation was calculated for the amount of change in 20-m time against the VAS score, HR, and each kinematic variable. Spearman's rank correlation was also used to assess the relationships among the amount of change in each kinematic variable and either the VAS score or HR. The significance level for all the analyses was less than 5 %.

3. Results

Table 1 shows the median and quartile deviation for each variable in the non-pressure and pressure conditions. The Wilcoxon matched-pair signed-rank test performed on the VAS score revealed that participants reported a significantly higher level of anxiety in the pressure condition than in the non-pressure condition (T = 2.34, p<.05), and the HR was significantly greater in the pressure condition than in the non-pressure condition (T = 2.54, p<.05), indicating that both cognitive anxiety and physiological arousal increased under the pressure condition. The Wilcoxon matched-pair signed-rank test performed on the 20-m time showed the marginal shortening of 20-m time by pressure (T = 1.82, p<.10). No significant difference was found in the kinematic variables.

The Spearman's rank correlation showed that the amount of change in HR and that in 20-m time had a strong negative correlation (r=-.75, p<.01), indicating that the greater the increment in HR, the greater the improvement in the 20-m sprint performance (Fig. 1). In addition, a significant strong positive correlation was observed between the amount of change in HR and that in the maximal angular velocity of the knee in the front leg (r=.78, p<.01), indicating that the greater the increment in HR, the greater the increment in knee extension speed (Fig. 2). Moreover, a significant negative correlation was observed between the 20-m time change and the change in the maximal angular velocity of the knee in the front leg (r=-.74, p<.01). This indicated that the greater the increment in knee extension speed, the greater the improvement in the 20-m sprint performance (Fig. 3). No significant correlation was observed in other combinations of variables.

Table 1. Medians and Quartile Deviations (QD) of Each Variable in the Non-Pressure and Pressure Conditions.

	Non-Pressure		Pressure		Wicoxon	
Variable	Median	QD	Median	QD	*Z* value	*p* value
20m time (s)	3.57	0.20	3.58	0.19	1.82	.07
VAS (mm)	15.00	23.00	23.17	28.25	2.34	.02*
HR (bpm)	108.65	5.14	111.95	8.44	2.54	.01*
Setting phase						
Angular displacement in the front block side						
Shoulder (deg)	-34.93	6.46	-34.95	5.51	0.59	.55
Elbow (deg)	1.38	1.52	0.89	1.97	1.04	.31
Hip (deg)	-5.95	5.53	-7.51	5.30	1.16	.25
Knee (deg)	69.88	9.28	70.59	9.84	1.48	.14
Ankle (deg)	18.75	4.16	17.63	4.26	1.10	.27
Angular displacement in the rear block side						
Shoulder (deg)	-33.05	5.77	-31.36	6.37	1.04	.30
Elbow (deg)	-1.03	3.62	-0.63	3.02	0.16	.88
Hip (deg)	-14.09	2.44	-16.50	3.40	0.72	.47
Knee (deg)	75.72	12.41	75.77	13.99	1.16	.25
Ankle (deg)	5.14	11.54	4.50	12.72	0.66	.51
Starting phase						
Angular displacement in the front block side						
Shoulder (deg)	29.32	11.16	29.07	13.43	1.46	.14
Elbow (deg)	-86.77	16.26	-86.78	16.86	1.10	.27
Hip (deg)	97.44	4.72	98.40	3.77	1.04	.30
Knee (deg)	58.21	13.49	55.33	12.28	0.60	.55
Ankle (deg)	39.97	9.51	42.04	9.62	0.03	.98
Angular displacement in the rear block side						
Shoulder (deg)	198.02	18.04	198.02	18.80	0.09	.93
Elbow (deg)	-48.98	14.91	-40.58	19.68	1.10	.27
Hip (deg)	3.09	11.74	2.97	10.42	0.57	.57
Knee (deg)	-29.49	9.65	-30.63	7.05	0.03	.98
Ankle (deg)	-5.10	5.16	-4.41	4.87	0.72	.47
Maximal angular velocity in the front block side						
Hip (deg/s)	418.20	38.69	414.78	33.32	0.97	.33
Knee (deg/s)	424.18	50.23	416.23	51.85	1.16	.25
Ankle (deg/s)	442.03	38.08	442.83	39.14	0.09	.93
Stride length (m)	1.13	0.06	1.12	0.07	0.21	.83

* p<.05

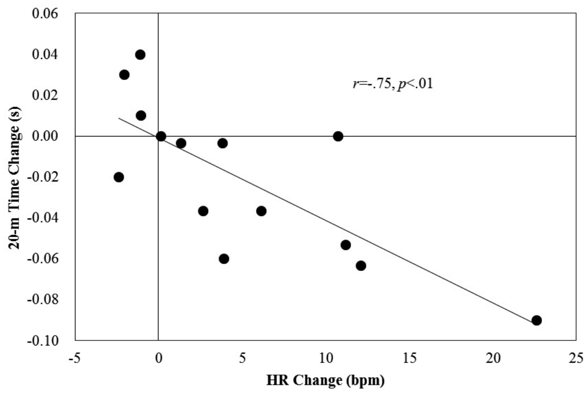

Figure 1. Relationship between the change in HR and that in 20-m time.

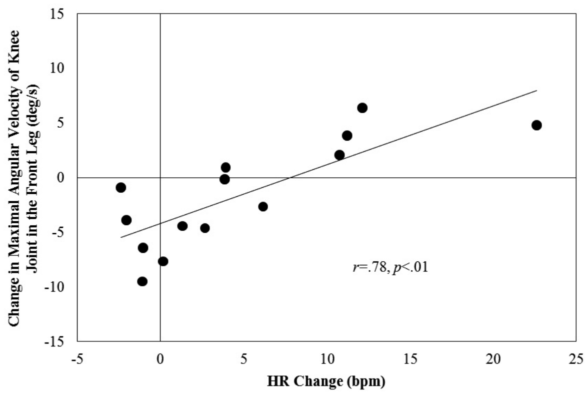

Figure 2. Relationship between the change in HR and that in maximal angular velocity of the knee joint in the front leg.

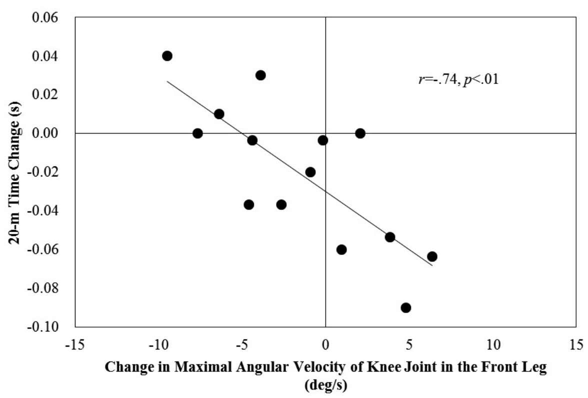

Figure 3. Relationship between the change in maximal angular velocity of the knee joint in the front leg and the change in 20-m time.

4. Discussion

The first purpose of the present study was to examine the influence of pressure on the psychological, physiological, behavioral aspects and performance of a sprint start. The comparison of VAS scores between non-pressure and pressure conditions confirmed that the present pressure instructions were effective on a subjective level. In the present study, the increment in the VAS score was approximately 10 mm, and the mean VAS score in the pressure condition was 38.50 mm, which was less than one-half of the maximal score. Therefore, the intensity of cognitive anxiety induced in the present study was relatively low. The pressure instruction also produced a significant effect on physiological arousal as the HR significantly increased from the non-pressure condition to the pressure condition. In the present study, the increased HR was approximately 5 bpm, and the average HR in the pressure condition was 117.90 bpm. Yoshie et al. (2009) reported that the HR of pianists in a competition with a large audience increased by approximately 35 bpm compared to that in a practice session. McArdle, Foglia, and Patti (1967) reported that sprinters had an average HR of 158 bpm immediately before a race. Therefore, the degree of physiological arousal in the pressure condition of the present study was comparatively low.

No significant difference was found in the comparison of 20-m time between the non-pressure and pressure conditions. It is, therefore, reasonable to conclude that the relatively low level of pressure induced in the present study was not sufficiently high to change the sprint performance. Incidentally, three participants received a cash reward for improved performance.

No significant change in the kinematic variables was found. This result indicated that movement kinematics in the setting and starting phases were not influenced by the pressure instruction. However, because of the marginal improvement in the 20-m time, it is possible to speculate that some changes occurred in movement kinematics in the running phase (i.e., after the first stride) that were not examined in this study. In the future, it is necessary to include a broader range of phases of a sprint to understand the kinematic changes under pressure.

The second objective of the present study was to investigate the relationships between the changes in psychological, physiological, behavioral aspects and performance under pressure. The correlation analyses demonstrated that higher physiological arousal is associated with improved performance in a sprint start. The greatest increase of HR among participants was 22.6 bpm, and this participant improved the performance to the greatest degree. On the other hand, participants who decreased HR seemed to perform less well. Theories to explain the relationship between physiological arousal and performance suggest that performance improves as physiological arousal increases when physiological arousal is relatively low (Hardy & Parfitt, 1991; Yerkes & Dodson, 1908). The results of the present study are consistent with these theories. However, those theories further suggest that the relationship between physiological arousal and performance would not be linear when the physiological arousal exceeds a certain threshold. Therefore, if participants faced stronger pressure, it is possible that different relationships would be presented. While the generalizability of the result of the present study is limited to situations in which only mild pressure is produced, further research is needed to clarify kinematic changes that mediate the relationship between physiological arousal and performance.

In addition, the significant relationship between the amount of change in HR and that in maximal knee angular velocity indicated that the higher physiological arousal is associated with higher movement velocity. However, the increase of HR would not always lead to the higher movement velocity. The increment more than 10 bpm would be needed for the increase of maximal knee angular velocity. Furthermore, the significant relationship between changes in 20-m time and maximal knee angular velocity was found, indicating that the higher movement velocity in the starting phase is associated with improved performance. However, performance improvement of 5 ms or more seems to require to increase maximal knee angular velocity under pressure.

Taken together, the results demonstrated that increased physiological arousal and maximal angular velocity of knee joint in the front leg by mild pressure plays a significant role in changing the performance in a sprint start. Although improved performance by mild pressure, which was found in the present study, has been predicted by the theories proposed to explain the relationship between physiological arousal and performance (e.g., Hardy & Parfitt, 1991; Yerkes & Dodson, 1908), the results of the present study suggested the importance of measuring behavioral index and its relationship with other indices. Future research should involve a higher level of pressure and more detailed analyses of movement kinematics and their relationship with psychology, physiology and performance in order to understand motor skills that require strength and speed under pressure.

References

Baumeister, R. F. (1984) Choking under pressure: Self-consciousness and paradoxical effects of incentives on skillfull performance. *Journal of Personality and Social Psychology*, **46**, 610-620.

Coh, M., Jost, B., Skof, B, Tomazin, K., & Dolenec, A. (1998) Kinematic and kinetic parameters of the sprint start and start acceleration model of top sprinters. *Gymnica*, **28**, 33-42.

Cooke, A., Kavussanu, M., McIntyre, D., & Ring, C. (2010) Psychological, muscular and kinematic factors mediate performance under pressure. *Psychophysiology*, **47**, 1109-1118.

Hardy, L. & Parfitt, G. (1991) A catastrophe model of anxiety and performance. *British Journal of Psychology*, **82**, 163-178.

Higuchi, T. (2000) Disruption of kinematic coordination in throwing under stress. *Japanese Psychological Research*, **42**, 168-177.

Houtman, I, L, D. & Bakker, F. C. (1989) The anxiety thermometer: A validation study. *Journal of Personality Assessment*, **53**(3), 575-582.

McArdle, W. D., Foglia, G. F., & Patti, A. V. (1967) Telemetered cardiac response to selected running events. *Journal of Applied Physiology*, **23**, 566-570.

Murayama, T., Tanaka, Y., Sugai, W., & Sekiya, H. (2007) The influence of time pressure on the execution of a motor skill. *Japan Journal of Physical Education, Health and Sport Sciences*, **52**, 443-451.

Oudejans, R. R. D. & Pijpers, J. R. (2010) Training with mild anxiety may prevent choking under higher level of anxiety. *Psychology of Sport and Exercise*, **11**, 44-50.

Pijpers, J, R, R., Oudejans, R. R. D., Holsheimer, F., & Bekkaer, F, C. (2003) Anxiety-performance relationships in climbing: A process-oriented approach. *Psychology of Sport and Exercise*, **4**, 283-304.

Tanaka, Y. & Sekiya, H. (2006) The influence of acute psychological stress on golf putting. *Japanese Journal of Sport Psychology*, **33**, 1-18.

Tanaka, Y. & Sekiya, H. (2010) The influence of audience and monetary reward on putting kinematics of expert and novice golfers. *Research Quarterly for Exercise and Sport*, **81**, 416-424.

Tanaka, Y. & Sekiya, H. (2011) The influence of monetary reward and punishment on psychological, physiological, behavioral and performance aspects of a golf putting task. *Human Movement Science*, **30**, 1115-1128.

Tanaka, Y., Urimoto, K., Murayama, T., & Sekiya, H. (2009) The influence of pressure on coordinative whole-body movement. *Japanese Journal of Sport Psychology*, **36**, 103-114.

Yerkes, R. M. & Dodson, J. D. (1908) The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, **18**, 459-482.

Yoshie, M., Kudo, K., Murakami, T., & Ohtsuki, T. (2009) Music performance anxiety in skilled pianists: effects of social-evaluative performance situation on subjective, autonomic, and electromyographic reactions. *Experimental Brain Research*, **199**, 117-126.