DETECTING PHYSICAL FATIGUE USING ACCELEROMETER IN BASKETBALL PLAYERS

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This study was to determine the feasibility of using an accelerometer to detect changes during fatiguing activities in basketball players. Eight male recreational basketball players performed a fatigue protocol with a set of basketball-related activities. A tri-axial accelerometer was used to monitor the changes in acceleration. The summated acceleration of each direction and the completion time were analyzed. The fatigue process was divided into three fatigue levels (0, 50, and 100 %). The results showed that the summated acceleration of the vertical direction was significantly different between 0 % and 100 % fatigue levels ($p < 0.05$) and had a positive link with the completion time ($r = 0.87$). These findings suggest that the accelerometer can be developed as a monitoring tool to differentiate between a non-fatigued and a fatigued condition in basketball players.

KEYWORDS: sensors, inertial measurement unit, wearable device

INTRODUCTION: Basketball is a team sport with various high-intensity intermittent movements such as jumping, sprinting, cutting and shuffling (Kong, Qi & Shi, 2015). Moreover, players of this sport need both aerobic and anaerobic abilities (McInnes, Carlson, Jones & McKenna, 1995) to extensively perform movements with their maximal efforts during training and competition. In such circumstances, basketball players commonly suffer from fatigue that negatively affects their own performance and even increases the risk of injury (Lewis, 2018; Mulazimoglu, Yanar, Tunca Evcil & Duvan, 2017). For these reasons, it is valuable to develop a fatigue monitoring approach to assist practitioners to maintain high quality training and make substitutions before the adverse effects are induced by prolonged fatigue.

To date, monitoring approaches for physical fatigue are still developing in sports fields. The measurement of the rating of perceived exertion (RPE) is an effective and useful method to monitor players' internal demands and fatigue state. The Borg's 6-20 RPE scales are widely applied in sports fields and the scale of 17 can be used to represent a sign of fatigue (Williams, 2017). Although the RPE is simply applied to distinguish individual fatigue status, it cannot offer real-time tracking resulting in the limited use during training and competition. On the other hand, fatigue-related changes in movements have been observed (Morin, Jeannin, Chevallier & Belli, 2006). Accordingly, detecting early stage fatigue through the real-time observation of movement changes may be feasible.

The accelerometer as one of emerging growth technologies has become the potential monitoring tool to quantify external demands and fatigue state of the athletes' individual movements during drill and competition (Bourdon et al., 2017). Some basketball-related studies used an accelerometer to collect the tri-axial acceleration data and then accumulate the rate of change in resultant acceleration to monitor training or external loads (Edwards et al., 2018; Fox, Stanton & Scanlan, 2018). However, the application of acceleration in response to fatigue has not been fully investigated yet in basketball. Recent studies placed a tri-axial accelerometer on lower back to identify the fatigue-related changes in body acceleration during a prolonged run and repeated sprints (Akenhead, Marques & Paul, 2017; Evans & Winter, 2018). Basically, basketball players need to equip themselves with sufficient capabilities of acceleration and deceleration for reaching and maintaining peak performance. However, these capabilities during training and competition are negatively influenced by fatigue resulting from repeated basketball-related activities. On the other hand, some studies indicated that fatigue impaired the abilities to maintain vertical displacement of center of mass (COM) and attenuate vibrations during movements (Girard, Micallef & Millet, 2011; Voloshin, Mizrahi, Verbitsky & Isakov, 1998). These changes in basketball players seem to not only cause a decrease in the accelerations of anterior-posterior and medial-lateral directions but lead to an increase in the volume of vertical acceleration. For these reasons, the change of summated accelerations in each direction may be a feasible method to detect signs of fatigue during competition or training. Therefore, this study aimed at determining the feasibility of using an accelerometer to detect fatigue-induced changes during repeated basketball-related activities in basketball players.

METHODS: Eight male recreational basketball players (age: 21.4 ± 2.7 years old; height: 175.6 ± 6.7 cm; weight: 71.8 ± 11.1 kg; years of playing: at least 3 years) without neuromuscular injuries in recent six months were recruited in this study. All participants signed the written informed consent in the form approved by the Institutional Review Board of the local University. Then, each participant performed a fatigue protocol with a set of basketball-related activities. These activities were designed based on the movements during a real basketball match and the execution sequence was fixed (as shown in Figure 1). When performing the protocol, they were asked to perform each trial with their maximal efforts and repeated until they fatigued. There was a 1-min rest between trials. Moreover, the RPE of each trial was recorded, and the individual fatigue condition was set at when the reported RPE value was greater or equal to 17.

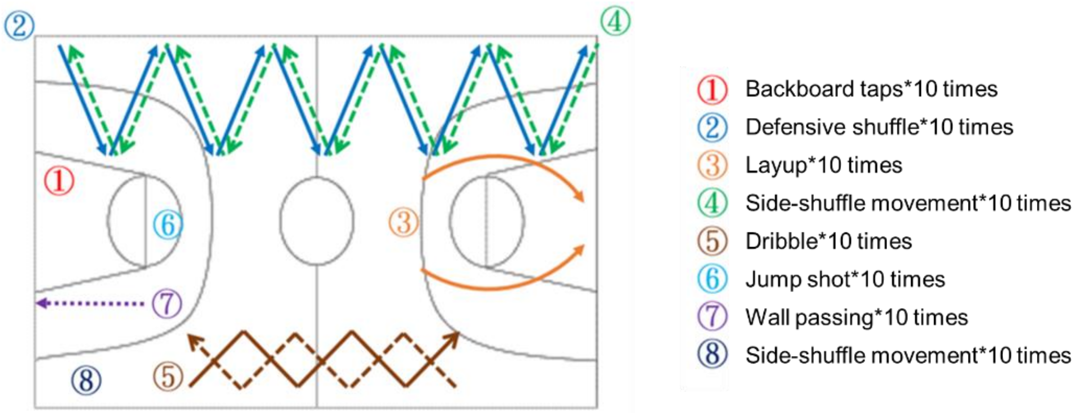

Figure 1: The order of the basketball-related activities in the fatigue protocol

A tri-axial accelerometer with a measurement range of ± 16 *g* and a sampling rate 148 Hz (Trigno™ Wireless IM, DelSys Inc, MA, USA) was attached on the lumbar spine of each participant and used to monitor the changes of acceleration during fatiguing activities. Based on the finished trials of each participant, three fatiguing levels (0, 50, and 100 %) were divided. The first trial was defined as the 0 % fatigue level (non-fatigue state), the median trial was defined as the 50 % fatigue level, and the last trial was defined as the 100 % fatigue level (fatigue state). The summation of the absolute value of total resultant acceleration and that of each axis including vertical (V direction), anterior-posterior (AP) and medial-lateral (ML) directions were collected and analyzed for each fatigue level. Moreover, the time to completion of each trial was recorded using a stop watch. A one-way repeated measure ANOVA was used to compare the differences of all parameters among fatigue levels. A post-hoc analysis using least significant difference was used for pairwise comparisons. Further, Pearson's correlation coefficient was used to test for correlations between completion time and the summated acceleration of each direction. All the significant levels were set at $p < 0.05$.

RESULTS: The mean number of trials completed was 4.6 ± 1.8. After the comparisons among three fatigue levels, significant differences were found in the completion time and the summated accelerations of AP and V directions ($p = 0.001$ and 0.027, respectively) and there were no significant results in the summated resultant and ML accelerations (both $p > 0.05$). Further post-hoc results, as shown in Table 1, showed that the completion time under the 100% fatigue level was significantly longer than that under the 0 % fatigue level, and there was no significance between the 50% and 100% fatigue levels in the completion time. Meanwhile, there was a significant increase in the summated acceleration of V direction under the 100%

fatigue level, when compared with the 0 % fatigue level (p = 0.022). Moreover, the summated accelerations of AP direction under the 50 % and 100 % fatigue levels were significantly decreased (p = 0.008 and 0.003, respectively), when compared with the 0 % fatigue level. Additionally, no significant difference between the summated acceleration results of other comparisons (p > 0.05) was observed.

Table 1: The comparisons of each variable among different fatigue levels

	Fatigue condition		
	0 % level	50 % level	100 % level
Completion time (seconds)	197.11 ±12.14	198.89 ± 13.20	204.10 ± 13.90*
Resultant acceleration (*g*)	36645 ± 2192	36485 ± 2448	37172 ± 2187
V direction acceleration (*g*)	30010 ± 2226	30490 ± 2478	31265 ± 2218*
AP direction acceleration (*g*)	10499 ± 1367	9879 ± 1275*	9806 ± 1296*
ML direction acceleration (*g*)	10869 ± 950	10374 ± 1268	10456 ± 1422

Note. AP: anterior-posterior; V: vertical; ML: medial-lateral.*p < 0.05 represents a significant difference when compared with the 0 % fatigue level.

Moreover, a significantly positive correlation between the completion time and the summated acceleration of V direction (r = 0.87, p < 0.001; as shown in Figure 1) was observed, while there were no correlations between the completion time and that of AP or ML directions (p > 0.05).

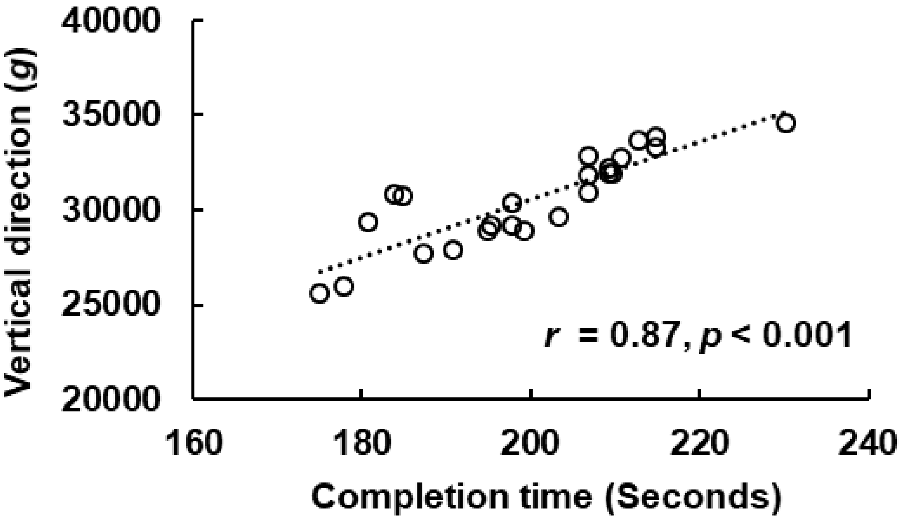

Figure 1: The correlation between the completion time and the pooled data from all conditions in the summated acceleration of vertical direction

DISCUSSION: This present study was designed to determine the feasibility of the accelerometer to detect the fatigue-induced changes in kinematics and performance during repeated basketball-related activities. The major finding of this study is that the completion time as sports performance was noticeably increased between the 0 % and 100 % fatigue levels; concurrently, the summated acceleration of the V direction was increased. Moreover, the summated acceleration of the V direction is positively related to the completion time. Although the AP acceleration was decreased between the 0 % fatigue level and one another, it had no correlation with the completion time. Apparently, fatigue state could be sensitively reflected by the vertical kinematical change which induces the impairment of sports performance. Generally, minimizing the excursion in the vertical COM displacement is the key to rapid change of direction and defense in team ball sports (Sasaki, Koga, Krosshaug, Kaneko & Fukubayashi, 2015). In addition, previous studies have documented the fatigue-induced impairment in the capacity to maintain vertical displacement of COM during movement and to attenuate vibrations during each landing (Girard et al., 2011; Voloshin et al., 1998). As a result,

these fatigue-induced changes reasonably explain that the increase in the total amount of vertical acceleration during repeated basketball-related movements were observed under the fatigue condition in this study. These findings also indicate that vertical kinematical changes could be used to differentiate between fatigue and non-fatigue condition during repeated basketball-related activities. Furthermore, this current study found an increase in the V direction, which is not consistent with a previous study (Akenhead et al., 2017). The previous study used the sum of the instantaneous rate of change in acceleration to monitor fatigue, and their results found a decrease in those of all directions. In contrast, this study used the summated acceleration. It is revealed that varying quantified methods in acceleration for fatigue could cause the differences, which needs to be noted and further understood.
In practice, fatigue is a critical factor in the impairment of players' movement and performance. The tri-axial accelerometers with the capability to real-time collect and analyze data can be used to validly detect the sign of physical fatigue, which is useful for players and coaches to adjust their training or competition arrangement for the minimization of adverse effect associated with prolonged fatigue.

CONCLUSION: These findings indicate that the accelerometer attached on the trunk can be a feasible monitoring approach to detect physical fatigue during basketball training and competition. Moreover, the change in the summated vertical acceleration is suggested to distinguish between a non-fatigued and a fatigued condition in basketball players.

REFERENCES

Akenhead, R., Marques, J. B. & Paul, D. J. (2017). Accelerometer load: a new way to measure fatigue during repeated sprint training? *Science and Medicine in Football*, 1, 151-156.
Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., Gabbett, T. J., Coutts, A. J., Burgess, D. J. & Gregson, W. (2017). Monitoring athlete training loads: consensus statement. *International Journal of Sports Physiology and Performance*, 12, 161-170.
Edwards, T., Spiteri, T., Piggott, B., Bonhotal, J., Haff, G. & Joyce, C. (2018). Monitoring and managing fatigue in basketball. *Sports*, 6, 19.
Evans, S. & Winter, S. (2018). Effects of fatigue on center-of-mass acceleration during a prolonged overground run. *Journal of Physical Therapy and Sports Medicine*, 2, 10-14.
Fox, J. L., Stanton, R. & Scanlan, A. T. (2018). A comparison of training and competition demands in semiprofessional male basketball players. *Research Quarterly for Exercise and Sport*, 89, 103-111.
Girard, O., Micallef, J.-P. & Millet, G. P. (2011). Changes in spring-mass model characteristics during repeated running sprints. *European Journal of Applied Physiology*, 111, 125-134.
Kong, Z., Qi, F. & Shi, Q. (2015). The influence of basketball dribbling on repeated high-intensity intermittent runs. *Journal of Exercise Science and Fitness*, 13, 117-122.
Lewis, M. (2018). It's a Hard-Knock Life: Game Load, Fatigue, and Injury Risk in the National Basketball Association. *Journal of Athletic Training*, 53, 503-509.
McInnes, S., Carlson, J., Jones, C. & McKenna, M. J. (1995). The physiological load imposed on basketball players during competition. *Journal of Sports Sciences*, 13, 387-397.
Morin, J.-B., Jeannin, T., Chevallier, B. & Belli, A. (2006). Spring-mass model characteristics during sprint running: correlation with performance and fatigue-induced changes. *International Journal of Sports Medicine*, 27, 158-165.
Mulazimoglu, O., Yanar, S., Tunca Evcil, A. & Duvan, A. (2017). Examining the effect of fatigue on shooting accuracy in young basketball players. *The Anthropologist*, 27, 77-80.
Sasaki, S., Koga, H., Krosshaug, T., Kaneko, S. & Fukubayashi, T. (2015). Biomechanical analysis of defensive cutting actions during game situations: six cases in collegiate soccer competitions. *Journal of Human Kinetics*, 46, 9-18.
Voloshin, A. S., Mizrahi, J., Verbitsky, O. & Isakov, E. (1998). Dynamic loading on the human musculoskeletal system—effect of fatigue. *Clinical Biomechanics*, 13, 515-520.
Williams, N. (2017). The Borg Rating of Perceived Exertion (RPE) scale. *Occupational Medicine*, 67, 404-405.

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