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On-Court Holistic Badminton Training Analytics Framework

Daniel Yong Wen Tan, Huong Yong Ting and Simon Boung Yew Lau

School of Computing, University College of Technology Sarawak, 96000 Sibu, Sarawak, Malaysia

Abstract: The aim of this research is to propose a holistic novice badminton athlete analytic framework in order to benchmark an athlete's performance during on-court training. In this research, we studied different analytic methods to be applied in badminton to measure an athlete's performance for his training in order to propose the ideal on-court training analytic framework. For quality of stroke, we used Microsoft Kinect to measure the athlete's consistency and benchmark his quality of stroke against an ideal model. To measure the force and the radian of the swing, we applied CoollangXiaoyu 2.0 to obtain the force, speed and radian of swinging motion. As for biometric data, we used Hexoskin to measure heart rate, heart rate variability, breathing rate and breathing volume. By using these three sensors during a performance assessment, we conclude that a coach would be able to obtain necessary data regarding an athlete's performance and use the data to plan for future training programme. Based on the proposed model, we can obtain data regarding the athlete's stroke quality, their fatigue level, maximum training intensity and performance progression. The analytic data will be crucial for a coach

Key words: Microsoft Kinect · Hexoskin · Coollang Xiaoyu 2.0 · Performance benchmark.

INTRODUCTION

Sport analytics is an essential part of sports economics. It has received wide spread acceptance among various popular sports such as soccer, basketball, racket games, golf, track and field and even e-sports [1]. In this paper, we focus on athlete performance analytics in badminton game. Badminton is a popular game around the world. The game receives significant popular support that it had been offered as part of the Summer Olympics event in 1992 at Barcelona until the recent Summer Olympics. Among the countries that produce top class players are China, Indonesia, Japan, Korea, Malaysia, India, Denmark, England and Taiwan. However, though badminton has been a popular sport, performance analytics in badminton has limited implementation. Usuallya badminton athlete's performance is benchmarked by their respective coach. There are someanalyticsthat can be done through quantitative method, such as numbers of lunges, duration taken in shuttle run andmaximum load in weight lifting. There are some analytics that are very difficult to measure quantitatively in badminton such as consistency of strokes, quality of strokes, body posture, phycological conditions and fatigue level. Even experienced coaches would find it difficult to measure and benchmark these conditions on their athletes. Analytics in athlete's performance may be the most important deciding factor to plan out the custom training routine specifically for an individual athlete. However, most athletes do not have the luxury of having individual coach who is willing to spend time coaching the athlete. There are after all, other athletes to pay attention to especially within a crowd of beginner level players. Special attention will only be given to outstanding athletes to receive personalised coaching.

Providing personalised coaching to an individual athlete is also challenging due to a lot of factors. Physical fitness, fatigue level, mental fitness, cognitive ability, talent and health are among the conditions that are difficult to judge based on naked eyes. Over-train an athlete will cause fatigue and injury, wasting precious time on recovery instead of training. Not enough training will cause the athlete unable to achieve the overloading state, a state where the body is pushed roughly 1.5 times over the current limit [2]. After having enough rest and recuperation the athlete will then reach a super compensation state, where performance would have increased to the maximum level. In order to measure these

Corresponding Author: Daniel Yong Wen Tan, School of Computing, University College of Technology Sarawak, 96000 Sibu, Sarawak, Malaysia.

conditions, special equipment or methods will need to be adopted to aid the coach to come to a conclusion on an athlete's performance. Every athletes' condition is different so determining the intensity of training will depend a lot on the analytics data collected. Analysis on athlete's current performance will greatly help the coach to determine the next course of training routine needed by the athlete.

Current Analytics in Badminton: In badminton, one of the most important assessment on performance is the ability to perform an acceptable stroke. The stroke is a motion of striking the shuttlecock from the ready position, moving on to the movements to strike the shuttle and finally, to return to the ready position. To analyse a badminton stroke, a review had been done by Tan [3], listed out several methods to analyse badminton motion. However, most of these methods require marker based equipment, which will affect an athlete's performance. These methods also cater to a specific stroke, such as serve and smash which is not enough as badminton contain a lot more stroke variability. The review also covers the work done by Ting [4], which utilise Microsoft Kinect to detect badminton motion naturally without any marker attached to the athlete. This method had proven to be able to capture most of the badminton strokes performed by a badminton player [5].

Heart rate data is an important analytic for sports science. Based on heart rate, an athlete's maximum training load as well as their fatigue level can be determined. Heart rate variability measures the stress level and the fatigues of athletes so that they do not overwork themselves. Traditional method of determining heart rate by taking through pulse requires an athlete to stop their current activity to measure their pulse. This method not only disrupts their training but also affect their training momentum as their body begins the process of cooling down. To determine training load, work had been done by Majumdar [6] to quantify training load in badminton. This method requires clinical lab testing as biochemical parameters will need to be measured. Another work had been done by Karvonen [7] to use heart rate (HR) to determine exercise intensity. Measuring heart rate to determine a training's intensity also requires specific monitoring gadgets, the most accurate devices usually requires subjects to take measurements in clinical lab environment.Nowadays, mobile wearable heart rate monitoring devices had been produced in the form of wrist band, watch, chest strap and even in the form of smart shirts.

Challenges in Badminton Performance Analytics: To accurately perform analytics in badminton performance requires a big budget. Marker-based motion sensors approach produced better results but came with a high setup cost and high maintenance cost. In addition to cost, athletes had to attach the markers onto their own body, which produce extra weight and the markers may hinder their natural movement. In order to cater for the inconvenience, athletes often have to move differently. Marker-based sensors require long setup time, calibrating the sensors as well as attaching them properly to the athletes.

Comparing with other high profit return sport, such as tennis, soccer, American football, golf and basketball, badminton did not enjoy the same high profit return in terms of prize money and sponsorships. Furthermore, the athletes are usually maintained by their respective national badminton association such as Badminton Association of Malaysia in Malaysia. The associations will provide the athlete with coaches as well as registering them for Badminton World Federation (BWF) accredited competitions. The athletes that are not in the association will need to have their own private coach, employing personal coach or by joining a local badminton club that has their own coach. For players that embarked their journey into the sport, a consumer grade performance analytics method will be the only option with low start-up cost and short set-up time with the accuracy of the analytics method increases by the day through continuous improvement on the technology. Furthermore, the analytic tools must be mobile as most of the time, the athletes will be training on the court, which is their battleground.

Relying on motion sensors alone is not enough to collect all the data required by the coach. The method proposed by Ting [4] will only benchmark players stroke quality and stroke consistency by joints. Other variables will need to be taken into account such as force of racket swing, the angle of the motion and biometric data such as HR, heart rate variability (HRV), breathing rate (BR) and breathing volume (BV). These data will be needed because badminton is a sport that requires a fair share amount of aerobic and anaerobic energy system. Proper training will need to be designed to cater for individual athlete's weakness. In order to determine their weaknesses, a holistic assessment approach will be needed.

Conceptual Model: To capture essential data on an athlete's performance so that proper training can be tailored for the athlete, a survey had been conducted to determine the important data needed by the coach. The population of coach that had been selected all obtained at least a level one coaching certification from BWF with three years of experience. Table 1 shows the data needed by the coaches and what the data will mean for the coaches.

Table 1: Data required by the coach for a training plan design

Data	Function
Heart Rate (HR)	Determine athlete's fitness and mental fitness.
Heart Rate Variability (HRV)	Measure stress level and fatigue level.
Breathing Rate (BR)	Determine activity intensity and activity recovery rate.
Breathing Volume (BV)	Determine athlete's fitness.
Stroke Consistency	Measure athlete ability to produce consistent strokes.
Stroke Force	Determine athlete ability to control the force applied to certain stroke.
Stroke Radian	Determine whether the athlete is swinging the racket correctly, especially on the wrist

Based on their requirements, we propose a model of badminton analytic framework, which can capture all of the data required by the coach without much human handling. Note that the survey only collects data that the coach could not obtain quantitatively by themselves and these data will aid them in planning for a training system. Strength, speed, flexibility and power can be easily assessed without aid from gadgets. We propose to implement three components to the analytic model which are: Microsoft Kinect for biomechanics measurement, gyro and accelerator sensor to measure force, radian and speed of stroke and a biometric sensor to measure HR, HRV, BR and BV.The framework will be used to assess the athlete's stroke performance, fitness and training intensity.

The main purpose of the Kinect sensor is to benchmark the athlete's stroke against the ideal stroke performed by elite athletes and to detect unnecessary movements or undesired movements which will be developed into bad habit for the athlete if it is not corrected there and then by the coach. Once the athlete can perform the basic stroke, the Kinect sensor will be used to assess the athlete's progress of mastering the stroke by measuring the athlete's consistency. To assess the quality of stroke, we used CoollangXiaoyu 2.0[1], a gyro and accelerator sensor attached to the racket as shown in Figure 1. The sensor itself is very light, with the weight of 5 grams, it does not greatly affect the overall weight of the racket during training. Figure 2 and Figure 3 show the data obtain during a backhand lift training by an athlete.The device came with an app accessible through Android or IOS. The sensor will detect the speed, force and the radian of the swing. These data allow the coach to assess the quality of the stroke performed by the athletes.

Fig. 1: CoollangXiaoyu 2.0 attached to a handle of a racket.

Fig. 2: General analysis of stroke count during a session.

[1]https://www.coollang-asia.com/badminton-sensor

Fig. 3: Swing details.

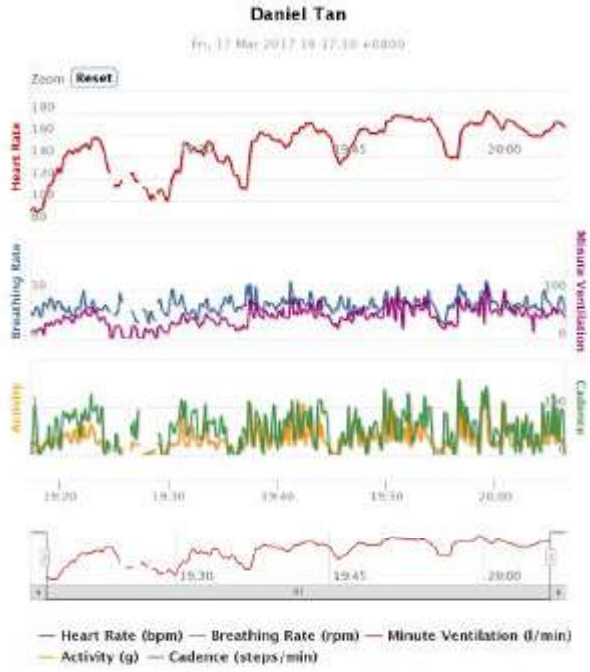

Fig. 4: Biometric data recorded by the smart shirt.

In addition to the two sensors mentioned above, our framework includes a biometric sensor in the form of a smart shirt developed by Hexoskin[2]. The smart shirt collects cardiac, respiratory, sleep and activity metrics such as HR, HRV, BR, BV, steps, calories and cadence. Figure 4 shows the data recorded by a single training session done by a doubles player. Based on the data, the coach will know whether the athlete had received the correct amount of training intensity for the session. The ideal heart rate training zone will depend on the athlete's heart-rate reserve, which is calculated based on age and resting heart rate. By using the smart shirt, the athlete need not worry about taking their HR as it can be displayed real time by the system.The coach will then have a good idea when the athlete is in a specific training zone based on the aerobic-anaerobic threshold heart-rate rangefor performance improvement and anaerobic training heart-rate range for high intensity training.

RESULTS

A novice athlete, who had average experience in playing badminton had been chosen to undergo a simple assessment to gather sample data with our framework. The data, such as age and resting heart rate was gathered before the experiment begins. The assessment consists of measuring the maximum amount of backhand lift with lunge movementdone in three minutes.

During the assessment, the athlete can choose to end the action if the athlete feels tired and unable to continue. The athlete was given five minutes of warming up before the assessment.During the assessment, the following data was collected: max HR, average HR, maximum BR, average BR, standard deviation (SD) of swing speed, swing force SD, radian SD and motion consistency SD.The standard deviation of motion data is used to determine the consistency of the athlete's swing data. These data will be used by the coach to properly plan for progressive training system for the athlete. Table 2 shows the data of the athlete and the results of the experiment.

Table 2: Data and result for athlete's backhand lift movement

Age			20					
Resting HR			50					
Heart Rate Reserve (220 – age – RHR)			150					
				Backhand Lift				
Duration	Action Completed	Max HR	Avg HR	MaxBR	Swing Speed SD	Swing Force SD	Swing Radian SD	Average Motion consistency
1 minute 31 seconds	18	176	160	69	4.02	1.63	17.92	0.54

[2]https://www.hexoskin.com/

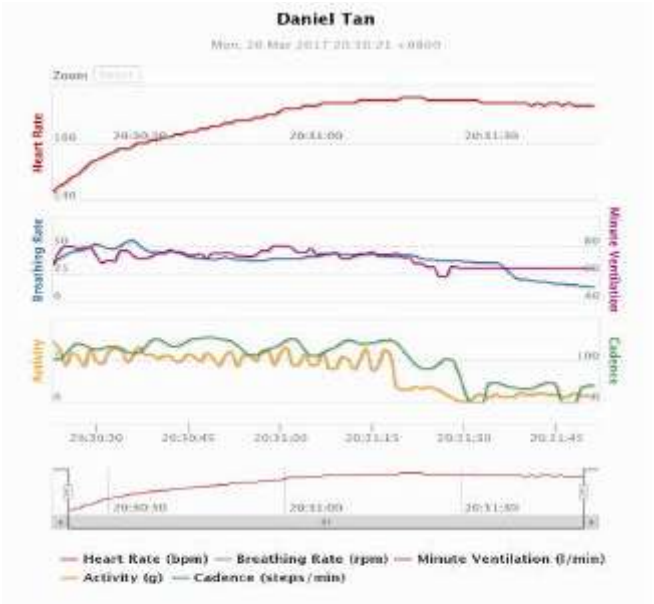

Fig. 5: Athlete's data measured by smart shirt

DISCUSSIONS

Based on the result, the athlete was able to complete eighteen set of backhand lift movement in one minutes and thirty-one seconds. We can conclude that:

- The athlete was not very fit with only HR reserve of 150.
- The athlete was utilising anaerobic energy system because the average HR is 106% of the HRR. Which means the athlete is not used to the exercise given.
- The athlete was at the limitat around the one minute mark as the cadence is rapidly dropping, indicating lowering of pace.
- The athlete was not consistent in the swing control as the SD of swing speed, swing force and swing radian is quite high.
- The athlete has consistent stroke motion as the SD for stroke consistency is very low.

With the assessment result, the coach can decide to use circuit training method to condition the athlete backhand lift action with the correct dosage of nine action per cycle with the maximum of three cycle. The coach would also need to pay attention to the athlete's ability to control the swing of the stroke to achieve the best consistency after several training sessions. These data will be collected throughout the training until the athlete is comfortable with the exercise. The training intensity and training load will need to be increased once the average HR drop to the range of eighty percent of the HRR.

CONCLUSION

In conclusion, we have successfully proposed a holistic training analytic framework to measure a badminton athlete's stroke performance. The proposed framework will quantitatively measure the athlete's stroke quality, stroke consistency, training intensity and general fitness by combining three sensors to assess the athlete. Based on the analytic information, the coach can provide a more precise training system for the athlete by reviewing which area the athlete is lacking at. The coach can also make sure that the athlete is actually giving all their effort into the training by achieving the optimum heart rate zone during their training session. Training load and intensity can be properly adjusted based on the analytic data provided by the proposed framework. Most of all, the proposed framework can be used on the badminton court anywhere with low setup coast and easy to operate.

Moving on, more experiments will be conducted with different levels of athlete ranging from beginners to elite players to benchmark the average performance by respective levels. With these data, the future system can further assist a coach by providing feedback to determine an athlete's level with minimal supervision from the coach during the athlete's training, freeing up valuable time for other athletes. Future work will include extending the range of vision-based senor to accommodate full court performance analytics.

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