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MODELING AND BALL SPEED VALIDATION OF A NEW SEPAKTAKRAW BALL LAUNCHER

Burhan Basyiruddin[1,2], Mohad Anizu Mohd Nor[1], Mohd Sumali Reduan[3], Zulfakri Mohamad[4], Shariman Ismadi Ismail[1]

[1]Faculty of Sports Science and Recreation,
Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

[2]Universitas Negeri Jakarta, Indonesia

[3]Persatuan Sepaktakraw Malaysia

[4]College of Engineering,
Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

*Corresponding author's email: shariman_ismadi@uitm.edu.my

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ABSTRACT

In recent years, the opponent's serve has become faster in sepaktakraw, resulting in the defensive work becoming a much harder task. Therefore, an effective training method to improve the defensive skills in sepaktakraw is imperative. Due to this reason, we have developed a new sepaktakraw ball launcher that can support sepaktakraw defence training. The aim of this study is to model and verify the ball's speed launched from the device. The prototype ball launcher was developed based on a parametric model of the launcher mechanism and real-world sepaktakraw ball kinematics. The prototype ball launcher's capability to launch sepaktakraw balls that reach real-world ball velocity was verified using a high-speed (480 Hz) camera motion analysis at four different launcher's speed capacities (70%, 90%, 95% and 100%). The results showed that the launched ball speeds from the experiment were lower than the theoretical launched ball speed for all speed capacities, only reaching the maximum speed of 59.4 km/h at 100% speed capacity. It can also be observed that the differences between the experimental and the theoretical speeds were increased at higher motor speed capacities, indicating that lower motor efficiency could be one of the possible causes of the launcher producing low ball speeds during launch. Though the top speed of the launched ball was close enough to the real-world average ball speed during a serve (60 km/h), based on the launcher's overall performance, further improvements are required before it is ready to be used for the training of elite athletes. Thus, several improvements to the ball launcher were suggested to increase the launched ball speed.

***Keywords**: launcher modelling, ball launcher, sepaktakraw, validity, high-speed camera*

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INTRODUCTION

When starting a sepaktakraw match, the ball is first served or crossed over the net into the opponent's court (ISTAF, 2021). Match performance analysis data has shown that the first serve is one of, if not the most important key performance analysis in sepaktakraw that determines the winning and losing team (Jamal, 2009). Recent advancements in sepaktakraw serve techniques have resulted in the maximum ball velocity to exceed 70 km/h (Sidhitlaw, 2000). This high-speed first-served ball has made defensive work a much more challenging task these days. In a separate study, regression analysis showed that the mean velocity of sepaktakraw serves ranges between 60.33 km/h to 66.42 km/ (Hamdan, et., al, 2012). Therefore, a launcher that is capable of generating a ball's speed between 60 to 70 km/h is desirable. Moreover, the practice models of receiving the first ball or defending in the game of sepaktakraw are varied according to the coaching and training methods. Typically, players use wall training, pairing with friends, or using manual assistive tools or equipment, usually feeding the ball by using a wooden racket, tennis racket, or other assistive devices (Hakim, 2010).

However, training with the above-mentioned methods certainly has limitations, because the condition of coaches or trainers could be inconsistent. This can result in uncontrolled variations in the ball feeding process, both in terms of the direction of the ball, the speed and variation of the desired ball feeding outcome (Isnaini, 2017). According to Brechbuhl et al. (2016), each specific training session requires an actual shot to replicate real-competitive matches for the training to be effective. For this reason, new technologies such as a sepaktakraw ball launcher are needed to improve training effectiveness. In addition, sepaktakraw has a field area of 13.4 x 6.1 m (ISTAF, 2016). For this reason, the sepaktakraw ball launcher should also be designed to be able to rotate to various sides, both to the right-left, and up and down direction. Ismail et al. (2019) investigated the ball distribution at the opponent's court during serve in sepaktakraw. The data collected for this study was based on a real competitive sepaktakraw tournament. The results indicated that the highest ball distribution is at the center and furthest section of an opponent's court, indicating that the served ball is not only fast, but also frequently travels far to the baseline area of the court. Therefore, a ball launcher that is capable of launching a high-speed ball is crucial.

There were several attempts to develop sepaktakraw ball launchers in the past (Ontan, 2008; Syafiq, 2008). In these studies, electric motors were used as the main mover in the devices . Typically, the ball launcher mechanism was equipped with two rotating rollers (wheels), with the rollers positioned on the top and bottom. Furthermore, another recent attempt to develop a sepaktakraw ball launcher was reported by Isnaini (2017), who used two rotating rollers (wheels) that were installed sideways, one each on the right and left side of the launch mechanism. However, in these past researches, the capability of these machines to replicate ball speeds based on real-match conditions have not been fully verified. Furthermore, the methods used to verify the ball speed launched by the devices were not described or explained, thus making these past works lacking clarity and validity.

Therefore, there is still a need to further develop and verify a reliable sepaktakraw ball launcher. This study aims to develop a sepaktakraw ball launcher with a verified ball speed capability that meets real world competitive match conditions.

METHODOLOGY

2.1 Parametric model of a ball launcher for sepaktakraw

In sepaktakraw, it is commonly known that typically the server will kick the ball at the upper part of the ball (*kuda*-kick serve technique) or at the back part of the ball (*sila*-kick serve technique). Both serve techniques would create ball movement around the frontal plane direction, rather than around the lateral plane direction. Therefore, a ball launcher mechanism with two counter-rotating rollers positioned on the top and bottom, in-between the ball (Figure 1) would be the most appropriate configuration in order to replicate real-match serve conditions, rather than sideways rollers configuration. A mathematical model of the launch mechanism of two counter-rotating rollers was adopted, as described by Gavali et al. (2022) and Wojcicki et al. (2011). In the model, several parameters were pre-determined based on existing known values as shown in Table 1.

Table 1: Pre-determined parameters related with the mathematical model of the launcher mechanism.

No.	Parameters	Unit	Values
1.	Sepaktakraw ball mass	Gram (g)	180
2.	Sepaktakraw ball radius	Centimeter (cm)	6.5
3.	Launched ball speed	Kilometer/hour (km/h)	100
4.	Roller radius	Centimeter (cm)	7.5
5.	Roller's coefficient of friction	-	0.2
6.	Roller's motor safety factor	-	2.0
7.	Gravity acceleration	Meter/second^2 (m/s^2)	9.81

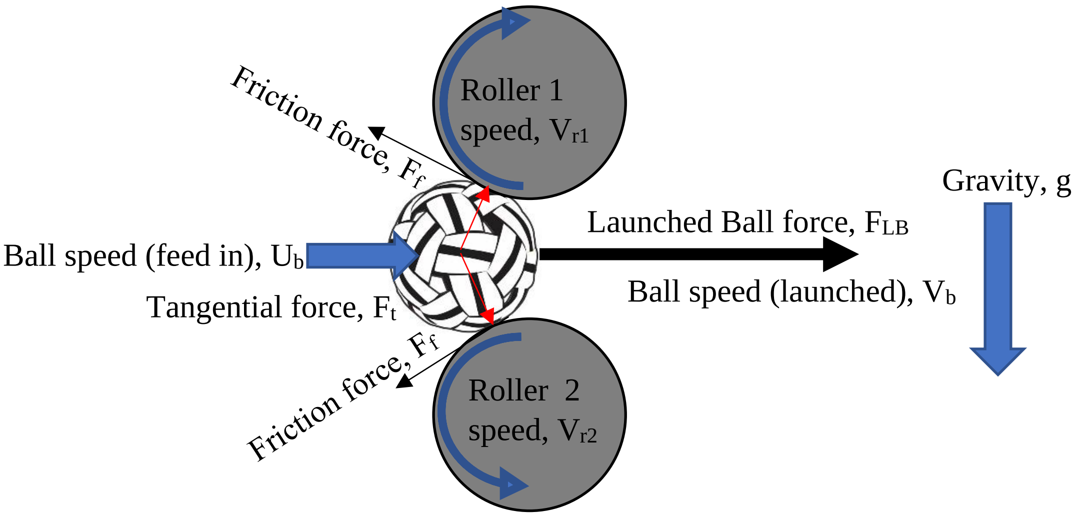


Figure 1: Configuration of the ball launcher mechanism and its associated forces and speed.

First, the force of the launched ball should be greater than the friction force between the ball and the roller to avoid any possible slips, given by the equation:

$$F_{LB} > 2F_f \quad (1)$$

Friction force, $F_f = \mu mg$

Where;

μ: roller coefficient of friction set at 0.2

m: ball mass (180g)

g: gravity acceleration at 9.81 m/s^2

Therefore, friction force, F_f = 353.16 N

Here, we understand that the launched ball force $F_{LB} > 2\ (353.16) = 706.32$ N

In order for the ball not to slip during feeding into the launcher roller, the launched ball force should be greater than 706.32 N.

In addition, the ball speed upon launched (V_b) will depend on the roller speed (V_r) given by the equation:

$$v_b = \frac{Vr1+Vr2}{2} \text{ for linear speed,} \quad (2)$$

Assuming that the roller linear speed: vr1= vr2, and the roller rotational speed: $\omega = \omega r1 = \omega r2$, we obtain:

$$v_b = r\, \omega r \quad (3)$$

The roller radius (*r*) was set at 7.5 cm (0.075 m) and the ball speed was 100 km/h (27.77 m/s) for further calculation. Therefore, the roller speed can be calculated as the following:

$$\omega r = v_b / rb,\ \omega r = \frac{27.77}{0.075} = 370.3 \text{ rad/s} \quad (4)$$

Converting the roller rotational speed to rpm:

$$\omega r\ (rpm) = \frac{370.3}{2\pi} \text{ x } 60 = 3537.6 \text{ rpm} \quad (5)$$

The rotational speed of the roller can be defined based on the assumption that the safety factor of the load acting in the motor shaft of the roller is 2.0 (Brokaw and Ellis, 2023), thus the roller's rotational speed should be set at 3537.6 rpm x 2.0 (safety factor). Therefore, the roller's rotational speed, $\omega r \approx 7075$ rpm.

2.2 Prototype of the sepaktakraw ball launcher mechanism

Data from the parametric model of the sepaktakraw ball launcher was used to develop a prototype of the launcher mechanism. As mentioned in the parametric model, the proposed roller rotation to reach a ball launch speed of 100 km/h was calculated to be around 7075 rpm. Therefore, it was decided that two-units of motorized rollers with a maximum speed of 7000 rpm were to be used for the prototype. Other specifications and details of the launcher prototype are shown in Table 2:

Table 2: Specification of the ball launcher prototype.

Parameter	Details
Launcher roller + motor	2 units of EVA-Roller, diameter 15 cm, width 11.5 cm with 24 V DC motor: maximum speed at 7000 rpm.
Roller arrangement	Two counter-rotating rollers positioned on top and bottom in-between the ball (top-spin)
Expected maximum ball launch speed	100 km/h
Feeding Ball	Feeding ball from top to bottom

Energy Source	Electrical or battery-operated 24 V, 20 Ah 7s3p 18650 lithium battery, 20000 mAh electric
Controller	Android application remote control to change the roller rotational speed (range 0 to 100%)

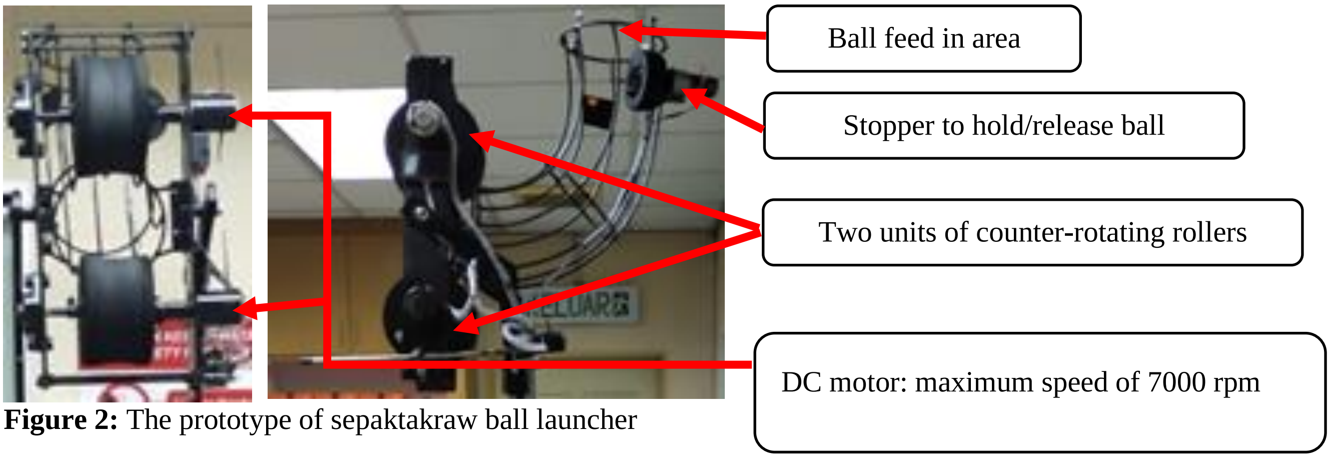
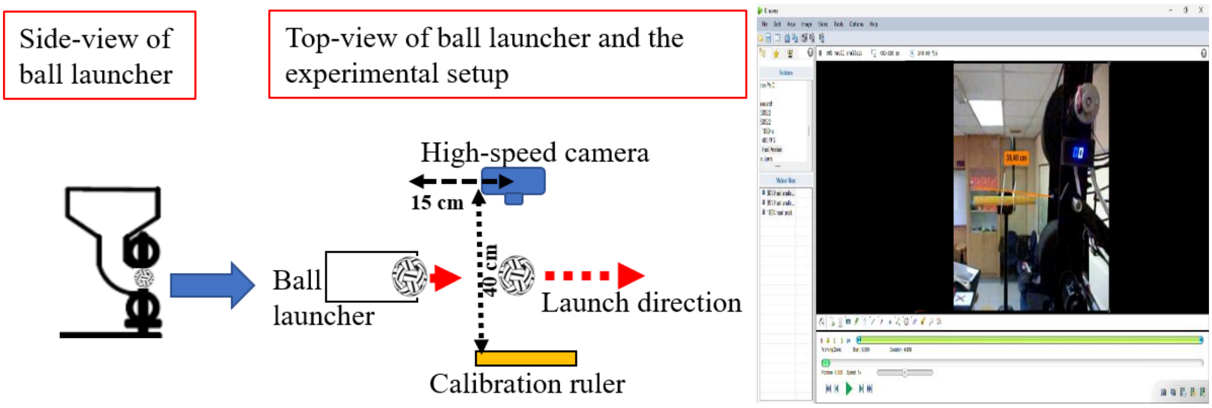


Figure 2: The prototype of sepaktakraw ball launcher

2.3 Ball speed measurement using a high-speed motion capture system

In order to verify the ball launcher's actual ball speed capability, an experiment to measure the launched ball speed using a high-speed camera was conducted. The experiment was carried out using a 480 FPS camera (CASIO- EXILIM EX-ZR70) to capture the movement of the ball at a high-frame rate, which will then be processed using the Kinovea (V.0.9.5) motion analysis software. Figure 3 shows the experimental setup and Kinovea motion analysis interface. In this experiment, the center of the high-speed camera lens was positioned 15 cm from the center of the ball's initial position before launching. Meanwhile, a 30 cm ruler, was positioned 40 cm from the camera to calibrate the ball's travel distance when it is in motion. Upon launching, the ball's motion was captured by the high-speed camera. The travel time of the ball from its initial position to 30 cm (length of calibration ruler) was then analysed to calculate the ball speed by dividing the travel distance to the time taken to cover the distance.



(a) (b)

Figure 3: (a) Experiment set-up of ball-speed verification during launch, and (b) Kinovea motion analysis software interface to measure ball-speed based on high-speed video (480 Hz).

2.4 Analysis

The ball was launched using various speed capacities (70%, 90%, 95% and 100%) and the speed was recorded. The highest recorded speed of the launched ball for each roller rotational speed capacity was selected for further analysis. The launched ball speed results from the experiment were then compared to the theoretical ball speed calculated based on the 100% (100 km/h).

RESULT AND DISCUSSION

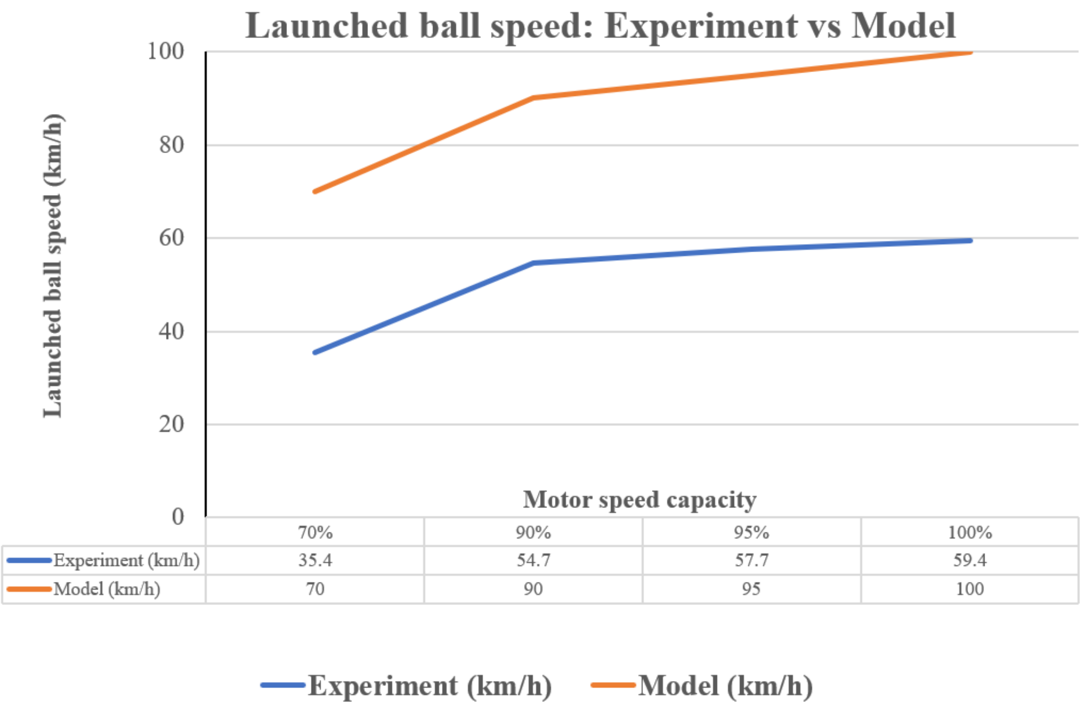


Figure 4: Comparison of launched ball speed results between experimental data and theoretical data.

Figure 4 shows a comparison of the experimental and theoretical launched ball speeds. It can be seen that in general, the launched ball speeds from the experiment were lower than the theoretical launched ball speed for all roller rotational speed capacities. In addition, the difference between the experimental and theoretical speeds was observed to increase as the motor speed increased, as shown in Figure 5. The speed difference was lowest at 70% roller speed capacity (34.6 km/h difference), whereas the largest speed difference was during 100% capacity (40.6 km/h difference). This observation suggests that the motor efficiency was decreased, possibly due to the loss of motor energy at higher rotational speeds. There are several possible factors that could have reduced the speed of the experimentally launched ball. One factor is the distance between the two wheels of the ball launcher that was in contact with the ball. Ponnusamy et al. (2015) who developed a table tennis ball launcher, similarly found that the experimental maximum ball speed (17.806 m/s) was less than 50% of the theoretical maximum ball speed (43.29 m/s). In addition, the rate of speed-drop further increased at the higher roller rotational speed. They suggested that the distance between the two rollers used for the launch mechanism was not optimal and a reduction of 1-2 mm of distance between the two rollers could increase the rollers' grip on the ball surface, which should increase the launched ball speed upon release. In our study, the distance between the two rollers used in the launch mechanism was set at 15 cm. Reducing this distance by 1-2 cm may increase the roller grip onto the ball, which could increase the launched ball speed.

Another factor that could have reduced the launched ball speed is the rise in the internal temperature of an electrical motor, especially when it is operating at maximum capacity. This is due to the copper winding inside the motor that becomes hot when the motor is operating at higher speeds (Choi et al., 2020). The role of the motor's copper winding element is to generate a magnetic field inside the motor, which is required for the motor to function. As the temperature of the copper rises, the strength of the magnetic field will be reduced and this would substantially affect the efficiency of the motor. This might explain the larger speed-drop of the experimental launched ball speed at a higher motor rotational capacity (40.6 km/h speed-drop at 100% motor capacity) when compared to a lower motor rotational capacity (34.6 km/h speed-drop at 70% motor capacity).

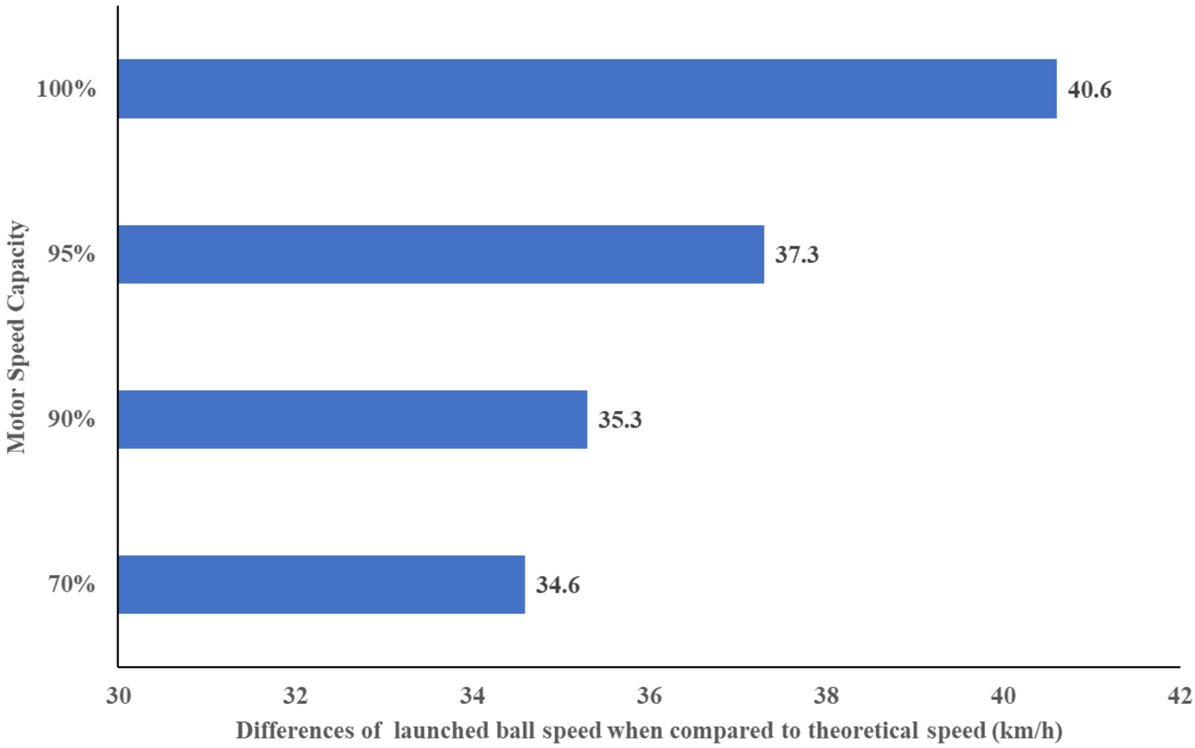


Figure 5: Differences of launched ball speeds between experimental and theoretical data.

Based on the findings of this study, it is clear that the sepaktakraw ball launcher prototype did not fully achieve the theoretical launched ball speeds. However, it can be seen that the maximum launched ball speed almost reached the real-world average service speed of 60 km/h. Thus, the ball launcher may still be appropriate for lower-level athletes, such as at the school or college level. However, the ball launcher prototype requires further improvement before it can be considered suitable for training elite athletes.

In order to increase the launched ball speed, we recommend several modifications. First, the motor capacity should be re-optimized to achieve the required ball speed. Using a more powerful motor for the ball launcher could potentially be the simplest modification required to improve the launched ball speed, especially to avoid the need to operate the motor at its maximum capacity. Second, the position of the throwing wheel (roller for the launcher mechanism) should be adjusted to optimize their grip on the ball's surface prior to launch, so that the resulting speed will be maximized. Third, the ball launcher could be mounted on a structure that is designed to minimize vibrations when the ball launcher is in use, thereby improving the motor efficiency.

CONCLUSION

The current developed ball launcher shows promise for use in sepaktakraw training, especially for lower level athletes such as school or college students. However, based on the ball launcher's current performance, further improvements and modifications are needed before it can be used for the training of elite athletes. Several improvements and modifications were suggested to allow the ball launcher to produce greater launched ball speeds.

AUTHORS' CONTRIBUTION

Burhan Basyiruddin: Idea, carried out this study and drafted the manuscript.
Shariman Ismadi Ismail: Review and drafted the manuscript, data interpretation, construct methodology
Mohad Anizu Mohd Nor: Statistical analysis and critical revision
Mohd Sumali Reduan: Data interpretation.
Zulfakri Mohamad: Study design and data collection
All authors read and approved the final manuscript.

CONFLICT OF INTEREST

No agencies or organizations have a conflict of interest in this study, which might be interpreted as influencing the findings or interpretation of this study. No financial resources were used to support this project.

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