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Development of a microcontroller-based detection tool for repulsion failure in long jump (dekto-lj*)*

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Abstract
Science and technology are developing rapidly, especially in the track and fields. Currently, plasticine is still used to detect repulsion failure in the long jump event. This manual method causes inaccuracies. Especially when the athlete's repulsion time is short. Therefore, it is necessary to develop an automatic detecting tool to assist the referee and improve the accuracy and efficiency of detecting long jump failure. This research aims to design a failure detection tool in long jump. This research uses a development methodology and uses quantitative and qualitative data analysis. The research participants were students, players and trainers. The final product produced was a sensor designed to detect failing long jumpers. Validation of the initial product design by athletic experts resulted in an average rating of 77% "good", while electronics experts rated 86% "very good". The second product design validation received an average rating of 85% "very good" from sports experts and 90% "very good" from electronics experts. In small-scale trial 1, 84.75% of athletes and 84.33% of coaches rated this product "very good". In the small-scale trial 2, 87.91% of the athletes and 87% of the coaches rated the product as "excellent". In the large-scale trial, 89.04% of the athletes and 90.67% of the coaches rated the product as "very good". This study concludes that the developed tool can detect repulsion failure when the athlete steps on the sensor. The long jump repulsion failure detection tool is worth developing to assist the referee in determining repulsion failure.
Keywords: Failure Detection, Long Jump, Indicator Board, Development, Sensor.

INTRODUCTION

Science and technology are rapidly advancing (Frevel, Beiderbeck, & Schmidt, 2022). Advances in technology have made it possible to use computers to perform biomechanical analysis to view recorded results of athletes' training sessions or matches (Santoso & Irwanto, 2018). With the development of science and technology that can be applied to various aspects of life, sports practitioners must always focus on innovation in the field of sports (Alif, Sudirjo, & Rasydiq, 2021). The emergence of innovative new ideas in various fields of science characterizes the development of science and technology (Beck et al., 2022), one of the fields of study is sports science (Jonvik, King, Rollo, Stellingwerff, & Pitsiladis, 2022). Sports is a discipline that utilizes technology as a means of support and support in facilitating all activities in the field of sports itself (Burns, 2015).

Science and technology can be very helpful in sports matches, particularly in supporting referees to assess and make decisions. However, it is important to note that technology should not replace the human element of the game (Kasih, Faridah, Siregar, Bangun, & Sinulingga, 2022). Science and technology play a crucial role in sports as they aid in managing athlete profiles and data collection, as well as in the training process, ultimately contributing to the development of athletes. It is important to maintain a clear and concise writing style, avoiding ornamental language and biased evaluations (Cossich, Carlgren, Holash, & Katz, 2023; Rizal, Hafidhurrifqi, & Mahmudi, 2018). Athletics is one of the sports that benefits greatly from advancements in science and technology (Lu, 2021). Athletics, also known as track and field, is considered the oldest sport in the world. It is often referred to as the 'mother' of all sports (Mother of Sports) (Fajar et al., 2022; Purnomo, 2017). The physical activities involved in athletic sports, such as walking, running, throwing, and jumping, were originally performed by ancient

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humans as a means of survival, development, and protection against threats and natural disturbances. It is important to note that these activities were not initially intended for leisure or entertainment purposes (Rahman, Hamdiana, & Naheria, 2022).

Athletics is a sport that comprises three disciplines: running, throwing, and jumping (Ganse, Ganse, Dahl, & Degens, 2018; Li & Li, 2021; Yu, 2015). In athletic competitions, each number has its own unique characteristics. One such characteristic is the long jump, where the athlete uses their strongest leg to make a horizontal jump and achieve the greatest distance possible (Antoni, Maifitri, & Fernando, 2020; Williams, 2024). The long jump is a combination of a run and a jump (Azuma & Matsui, 2021; Ren, Luo, & Chu, 2022). The distance of the jump will be greater if the coordination between running and pushing off is executed correctly (Muhammad, 2020). The technique for the long jump involves four stages: approach run-up, take-off, flight through the air, and landing (Čoh, Žvan, & Kugovnik, 2017).

The repulsion stage is a crucial aspect of the long jump because it determines the validity of the jump (Candra, Setyawati, & W, 2017). In this technique, the athlete propels themselves off the board using their strongest leg, converting horizontal speed into vertical speed (Ren et al., 2022). During the repulsion phase, athletes should aim to swing their legs as quickly as possible, increase their running speed, shorten the repulsion time, and select the appropriate repulsion angle (PAVLOVIC, 2016). In the sport of long jump, the takeoff is executed from a board or block that is horizontally placed and marked according to the starting line and landing area. The marked area is the only valid area for the jumper (Makaruk, Starzak, & López, 2015).

The athlete fails the jump if their repulsion touches the edge or area of the board/block closer to the landing place. Plasticine on the board/block serves as an indicator of jump validity and as a support for the athlete during the jump (World Athletics 2020). In long jump sports, the criteria for determining the validity of a jump are still determined manually or solely by the referee's visual observation (Yang & Bian, 2021). In manual judging, especially when the athlete has limited time to repel the projectile, the referee may overlook the athlete's feet during the repulsion phase (Jiang dan Yan 2021).

If an athlete's feet only lightly touch the plasticine and do not leave any marks, it can be difficult for the referee to determine the validity of the jump, leading to potential debate. Additionally, if the athlete's foot lands on the plasticine with too much force, it can cause damage to the plasticine or duct tape due to the repulsive force of the foot (Candra et al., 2017). In multi-event competitions such as the Asian Games, Olympics, and other major events, technology has been implemented to assist referees in determining the validity of an athlete's jump. Cameras record the jumping process and play it back in slow motion, allowing for a more accurate assessment. This objective method eliminates the need for subjective evaluations and reduces the time required to make a decision.

Researchers aim to develop an innovative tool that can directly and automatically determine the validity of a jump. The tool will be accompanied by a camera that can record slow motion to strengthen the evidence of the jump in case of a disagreement between the referee, coach, or athlete. Ultrasonic sensors and Light Dependent Resistor (LDR) sensors are being used in the development of this tool. The sensor will be connected to a buzzer, flag indicator, laser, and camera. The researchers aim to develop a long jump failure detection tool that can assist referees in quickly and accurately determining the validity of a jump. This tool will provide solutions for assessing jump validity.

METHODS

Research Type

Research and Development (R&D*)* is a type of research to develop a product, through the stages of planning, production and testing the validity of the resulting product (Sugiyono, 2019). The development process used in the development of long jump repulsion failure detection tools consist of 10 steps consisting of: (1) potential and problem; (2) gathering information; (3) product design; (4) validation of design; (5) revision of design; (6) test the product; (7) product revision; (8) trial of usage; (9) product revision; and (10) mass production.

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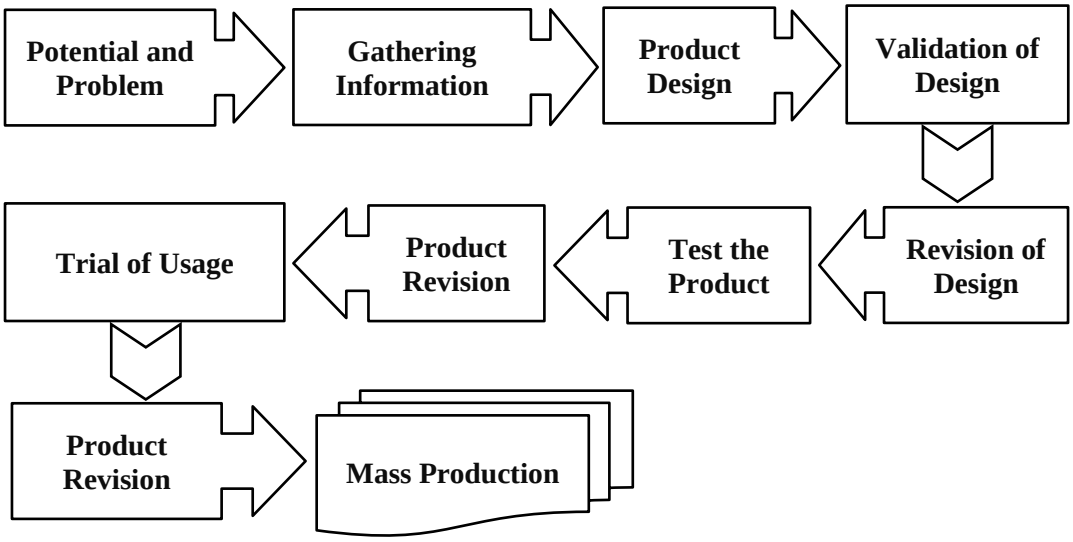

Figure 1. Research and Development (R&D) Method Steps

Research Subject

The subjects in this study were students, athletes, and athletic trainers. In the product testing phase, there are two phases, namely small-scale trial 1 and small-scale trial 2. In small-scale trial 1, researchers involved 25 UNNES student athletes as respondents, and in small-scale trial 2, 30 students were involved. While in the large-scale trial stage involved 60 students and 8 long jump athletes Jawa Tengah.

Data Analysis

The data used in this study is descriptive quantitative (Sandu Siyoto & Sodik, 2015). The research instrument used was a questionnaire using a range of values on a Likert scale, namely: 1) strongly disagree, 2) disagree, 3) disagree, 3) agree, and 5) strongly agree (Sugiyono, 2019). The questionnaire contains several questions or statements regarding the aspects assessed in the long jump error detection tool. The questionnaire was given to subjects, coaches, material experts and media experts. To determine the evaluation of the product developed using the formula:

$$\boldsymbol{P = \frac{\Sigma_i}{\Sigma_j} x 100\%}$$

Description : **P** = Percentage
Σxi = Total score from respondents
Σxj = Total maximum score
100% = Constant

After all is calculated, the scores will be classified into five categories, as follows (Pranatawijaya, Widiatry, Priskila, & Putra, 2019):

Table 1. Grading Scale

Percentage (%)	Classification
80 - 100	Very Good
60 – 79	Good
40 - 59	Pretty Good
20 – 39	Not Good
0 - 19	Very Bad

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RESULTS AND DISCUSSION

Results

A. Product Prototypes

Roughly, the product developed uses Arduino uno R3 as the programming brain, a laser pointer as the light distributor, LDR sensor as the light receiver which is transmitted to the Arduino which then produces output to the buzzer in the form of sound and a red flag indicator. And ultrasonic sensors to detect the athlete's movement, to automate the camera recording, and PIR sensors to stop the camera recording.

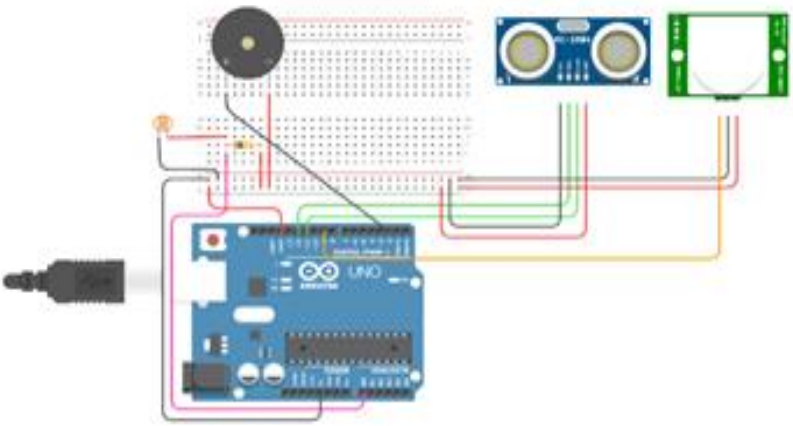

Figure 2. Arduino Schematics

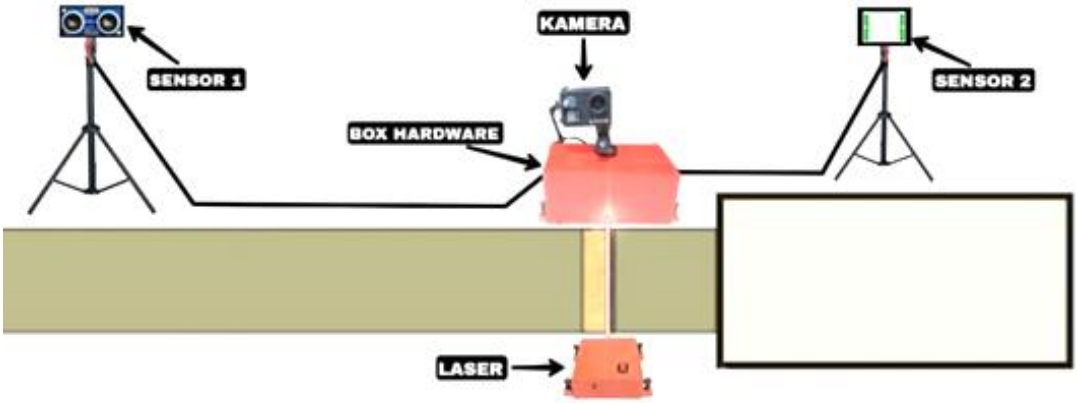

Figure 3. Tool Installation on Track

B. Initial Product Validation

The resulting product has gone through various stages to produce a final product in the form of a repulsion failure detection device that is effectively used to assist the performance of referees in long jump competitions. In addition, the resulting product has the advantage of being automatic because it uses a microcontroller. This study involved 3 expert validators, namely media experts (1 electronics expert) and material experts (2 athletic field experts). This validation aims to determine the advantages or disadvantages of the new product produced. Data obtained from evaluation and assessment sheets in the form of questionnaires regarding product quality accompanied by a sheet of suggestions and input from experts.

The results of the first product design validation by electronics experts obtained a percentage of **86%** in the **"Very Good"** category, while athletic experts obtained an average percentage of **78%** in the **"Good"** category. The results of the first stage of product validation obtained suggestions for improvements and revisions to the product as follows:

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Table 2. First Stage Product Design Revision

Revised Section	Reason for Revision	Suggestions
- The distance between the laser and the LDR sensor must be considered	- Laser and sensor must be symmetrical	- Installation on the repulsion boundary line must be accurate
- Sensor sensitivity	- Lack of sensitivity when repelling quickly	- Adjusted again
- Alarm sound	- Not clearly audible	- Turn up the volume again
- Light beam	- Not bright enough	- Explained more
- The camera	- Can be connected to a laptop and the recording results can be seen clearly	- Connect to laptop

The results of the second stage product design validation by electronics experts obtained a percentage of **90%** in the **"Very Good"** category, while athletic experts obtained an average percentage of **85%** in the **"Very Good"** category. The results of the second stage of product validation obtained suggestions for improvements and revisions to the product as follows:

Table 3. Second Stage Product Revision

Revised Section	Reason for Revision	Suggestions
- Plus legs on the hardware container part	- Makes it easy to align the laser beam with the sensor hole	- Plus legs
- The height of the sensor with plasticine is noted	- So that the sensor is not too high or low plasticized	- Customized height

C. Small-Scale Product Trial 1

Small-scale trial 1 involved 25 FIK UNNES students majoring in PKO 2022, and 2 athletic trainers. The following are the results of the small-scale trial 1 recapitulation:

Table 4. Small-Scale Trial Data 1

No.	Aspects Assessed	Σ	
		Athlete	**Coach**
1	Originality	108	25
2	Functional	457	38
3	Advantages	575	75
4	Comfort & Safety	449	23
5	Effectiveness & Efficiency	-	26
6	Economical	-	19
7	Compatibility	-	28
8	Completeness	-	19
Total Score		**1589**	**253**
Score Maximum	(5 x 15 statement x 25 Athlete)	**1875**	**300**
	(5 x 30 statement x 2 Coach)		
Percentage		**84,75%**	**84,33%**
Category		**Very Good**	**Very Good**

Based on the table above, shows that the athlete's assessment of the product developed obtained a percentage of **84.75%** in the **"Very Good"** category. While the coach's assessment obtained a percentage of **84.33%** in the **"Very Good"** category. To complete the data and as part of the data

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analysis, namely by examination and discussion by experts. Product validation on small scale trial 1 by electronics experts obtained a percentage of **92%** in the **"Very Good"** category and athletic experts obtained an average percentage of **87%** in the **"Very Good"** category. The revision suggestions from experts and coaches are as follows:

Table 5. Product Revision

Revised Section	Reason for Revision	Suggestions
- The buzzer sound is not loud enough	- Less clearly audible	- Turn up the volume again
- Motion detection sensor	- Less sensitive	- Increase sensitivity
- White flag	- As a sign of successful repulsion	- Plus white flag
- Fix the sensor	- Weak	- Sensors must be checked with a quick motion

After making improvements according to the revision suggestions for the product and feeling that all functions are better, the product is ready to be tested on a small scale 2.

D. Small-Scale Trial 2

This small-scale trial 2 involved 30 FIK UNNES students majoring in PKO 2022, and 2 athletic trainers. The following are the results of the small-scale trial 2 recapitulation:

Table 6. Table Small-Scale Trial 2

No.	Aspects Assessed	Σ	
		Athlete	**Coach**
1	Originality	134	26
2	Functional	599	43
3	Advantages	692	77
4	Comfort & Safety	553	25
5	Effectiveness & Efficiency	-	27
6	Economical	-	19
7	Compatibility	-	25
8	Completeness	-	19
Total Score		**1978**	**261**
Score Maximum	(5 x 15 statement x 30 Athlete)	**2250**	**300**
	(5 x 30 statement x 2 Coach)		
Percentage		**87,91%**	**87%**
Category		**Very Good**	**Very Good**

Based on the table above, shows that the athlete's assessment of the product developed obtained a percentage of **87.91%** in the **"Very Good"** category. While the coach's assessment obtained a percentage of **87%** in the **"Very Good"** category. To complete the data and as part of the data analysis, namely by examination and discussion by experts. Product validation on small scale trials 2 by electronics experts obtained a percentage of **94%** in the **"Very Good"** category and athletic experts obtained an average percentage of **89%** in the **"Very Good"** category. The revision suggestions from experts are as follows:

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Table 7. Table Product Revision

Revised Section	Reason for Revision	Suggestions
- **Buzzer sound is not loud enough**	- Weak	- To be reset so that it is hard because it is used in the field

E. Large Scale-Trial

This large-scale trial involved 68 respondents including 60 FIK UNNES students majoring in PKO 2022, 5 athletes from KKO Surakarta long jump athletes, and 3 PPLOP Jawa Tengah long jump athletes, and 2 coaches. The following are the results of the large-scale trial recapitulation:

Table 8. Large Scale-Trial

No.	Aspects Assessed	Σ	
		Athlete	**Coach**
1	Originality	285	27
2	Functional	1517	46
3	Advantages	1536	80
4	Comfort & Safety	1203	26
5	Effectiveness & Efficiency	-	30
6	Economical	-	20
7	Compatibility	-	24
8	Completeness	-	19
Total Score		**4541**	**272**
Score Maximum	(5 x 15 statement x 68 Athlete)	**5100**	**300**
	(5 x 30 statement x 2 Coach)		
Percentage		**89,04%**	**90,67%**
Category		**Very Good**	**Very Good**

Based on the table above, shows that the athlete's assessment of the product developed obtained a percentage of **89.04%** in the **"Very Good"** category. While the coach's assessment obtained a percentage of **90.67%** in the **"Very Good"** category.

Discussion

This development research aims to develop a repulsion failure detection tool in the long jump. The product that has been developed can help and make it easier for the referee/judge to know whether or not the athlete's repulsion is valid in the long jump competition, because this product is equipped with a failure detection sensor and a camera that can record the athlete's repulsion as well as a flag indicator and buzzer/alarm that will move and sound if the athlete steps on the sensor when repelling.

Indicators to determine the validity of a jump are still manual or completely dependent on the referee's vision. It should be noted that this manual assessment sometimes the referee is less careful in paying attention to the athlete's feet when repelling, especially when the athlete's time to repel is relatively short (Jiang & Yan, 2021). The developed product can help the referee decide quickly whether the athlete failed to make a repulsion because this tool is equipped with a buzzer/alarm sound and a flag indicator, so that it can help the performance of the referee/judge.

The product developed does not violate the rules set by the IAAF, because this tool can be installed outside the long jump track. Installation of this tool is also easy, only need to attach the cable according to the existing socket and the tool is ready to use. This tool is also equipped with a camera that records the athlete's repulsion, so that if the athlete can see the results of the repulsion that has been done, the athlete can see the results of the repulsion.

The resulting product has gone through various stages so as to produce a final product that is ready to be tested for mass production. The results of this study are in line with the research of Candra et al. (2017) entitled "Alat Sensor Getaran Pendeteksi Kegagalan pada Papan Indikator Lompat Horizontal".

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The results of this research show some significant progress. Expert validation results for DEKTO-LJ showed an increase, with electrical expert assessment reaching 94% compared to 81.25% in the previous study. Ratings from coaches and athletes also improved, with DEKTO-LJ getting 90.67% from coaches and 89.04% from athletes, compared to 85.42% and 85.83% in the previous study.

Based on data analysis of the research results, the following data were obtained:

1. The validation data of small-scale trial 1 products by electronics experts obtained an average percentage of 90% in the Very Good category and athletic experts obtained an average percentage of 85% in the Very Good category. The results of the questionnaire from the coach obtained an average percentage of 84.33% in the Very Good category, and the results of the questionnaire by students / athletes obtained an average percentage of 84.75% in the Very Good category**.**
2. Product validation data of small-scale trial 2 by electronics experts obtained an average percentage of 92% in the Very Good category. Product validation data for small-scale trial 2 by electronics experts has increased compared to small-scale trial 1 by 2%. Athletic expert data obtained an average percentage of 86% in the Very Good category. The validation data of small-scale trial 2 products by athletic experts has increased compared to small-scale trial 1 by 1%. The results of the questionnaire from the coach obtained an average percentage of 87% in the Very Good category. The data from the trainer's questionnaire on small-scale trial 2 increased compared to small-scale trial 1 by 2.67%. And the results of the questionnaire by students / athletes obtained an average percentage of 87.91% in the Very Good category. The data from the athlete questionnaire results on small scale trial 2 also increased compared to small scale trial 1 by 3.16%.
3. Large-scale trial product validation data by electronics experts obtained an average average percentage of 94% in the Very Good category. Large-scale trial product validation data by electronics experts has increased compared to small-scale trials 2 by 2%. Athletic expert data obtained an average percentage of 89% in the Very Good category. Large-scale trial product validation data by athletic experts has increased compared to small-scale trials 2 by 3%. The results of the questionnaire from the coach obtained an average percentage of 90.67% in the Very Good category. The data from the trainer's questionnaire on the large-scale trial increased compared to the small-scale trial 2 by 3.67%. And the results of the questionnaire by students / athletes obtained an average percentage of 89.04% in the Very Good category. The data from the athlete questionnaire results on this large-scale trial also increased compared to the small-scale trial 2 by 1.13%.

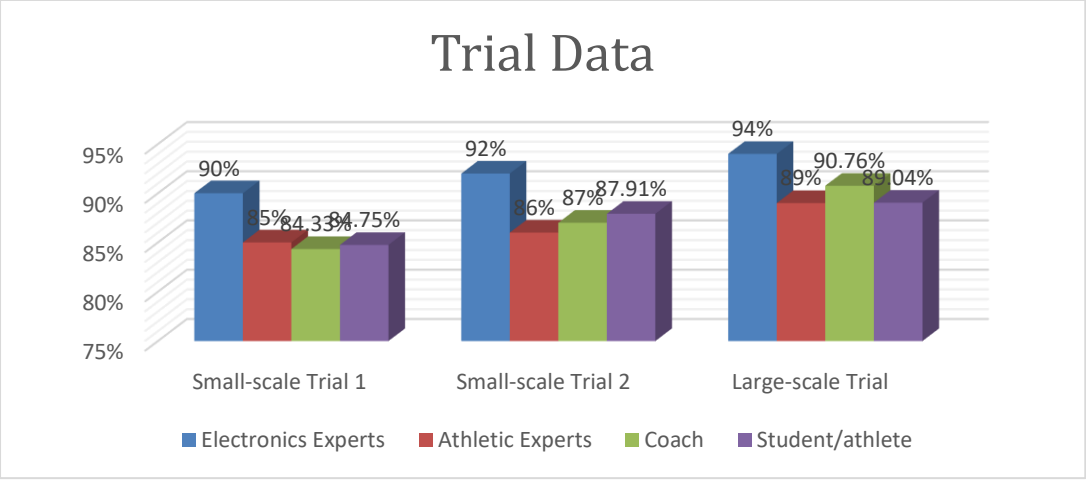

Figure 4. Improvement of Trial Result Data

Based on this diagram, it can be concluded that the data from the trial results has increased. The development of this device for detecting the failure of a long jump platform (DEKTO-LJ) opens up horizons for future research. Future research can focus on making the sensors and components weatherproof, as one of the drawbacks of this device is that it cannot be used in rain. Improving the stability of the sensor to reduce the detection error that still occurs in this tool DEKTO-LJ, further research is needed to improve the stability of the sensor. Future research can create applications that are connected to DEKTO-LJ to make it easier for coaches and athletes to access real-time data and perform performance analysis.

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CONCLUSION

The resulting product has gone through various stages so as to produce a final product in the form of a repulsion failure detection tool in the long jump with the name (DEKTO-LJ). Based on the results and discussion that has been described, it can be concluded that:

1) The product can detect the failure of leg repulsion when the athlete steps on or touches the sensor.
2) The product developed does not violate the rules set by the IAAF, because this tool can be installed outside the long jump track.
3) This tool is equipped with a camera that records the athlete's repulsion, so that if the athlete can see the results of the repulsion that has been done.
4) The developed product can be used for training.

This research is expected to provide benefits to athletics, especially the long jump. This research certainly still has weaknesses that must be improved for further research, here are some weaknesses in this development product:

1) Cannot be used when it rains.
2) The camera must be given an additional switch button to display the recorded video results to the laptop because the camera does not support when directly recording via a laptop.
3) Symmetrizing the laser on the LDR sensor hole is quite difficult because it must be completely symmetrical with the boundary line of the repulsion board.
4) Sometimes the tool sounds itself because the sensor is less stable.

Suggestions that researchers can provide for future product improvements are:

1) Products need to be tested in several athletic matches.
2) For further researchers, this tool can be refined by paying attention to the weaknesses that exist in this tool.
3) For the organization, this tool is expected to be patented and used in athletic competitions.

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