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The Effectiveness of Developing a Hand Grip Strength Training Module for Athlete Rock Climbers in Semarang Based on IoT Smart Bracelet

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Abstract
Rock climbing is a competitive sport that requires high grip strength, muscle strength, and endurance during climbing activities. However, monitoring athletes' handgrip training is often subjective and does not utilize technology capable of providing accurate data. This research aims to develop an Internet of Things (IoT)-based handgrip training module using a smart bracelet to improve training effectiveness and facilitate monitoring of athletes' training results. This research employed a Research and Development (R&D) method based on the Borg and Gall model. The research stages included needs analysis, product design, product development, expert validation, product trials, and product revision. The resulting product is a structured handgrip training module integrated with an IoT-based system capable of recording grip strength and duration in real time. The development results showed that the resulting module was deemed feasible based on expert validation and can facilitate more targeted training implementation and facilitate objective monitoring of training results, Based on the results of the normality test using the Shapiro-Wilk method, it was found that all handgrip strength measurement data, both in the pretest and posttest for the right and left hands, had significance values (Sig.) greater than 0.05. This module is expected to improve training effectiveness and support the development of more precise, data-driven training programs compared to manual methods.

Keywords: each hand grip strength; rock climbing; training module; iot smart bracelet; sport technology

1. Introduction

Sport is a physical activity carried out in a planned and systematic manner to improve physical fitness and health (Adi S, Wahyu Arbanisa, 2023). Over time, sport has evolved beyond simply maintaining health and fitness to become a competitive sport, requiring optimal performance through a structured and sustained training program (Saleh et al., 2022). By utilizing a sports science approach, training programs can be tailored to the athlete's physiological needs, thereby minimizing the risk of injury and optimally enhancing performance (Daulay et al., 2025). In sports science, competitive sports are understood as sports activities oriented towards achieving maximum results through a structured and continuous training process (Pangastuti, 2022). A systematically designed training program that takes into account physical condition components such as strength, endurance, speed, coordination and flexibility plays a major role in improving athlete performance (Sultan Brilin Susandi Eka Wahyudhi et al., 2023). In addition, proper management of training components will help athletes achieve peak performance during the competition (Bastinus, 2019).

One of the competitive sports that requires high levels of physical ability is rock climbing. Grip strength and endurance are key factors in determining climbing success, as the finger and forearm muscles work intensely to maintain body position on the climbing wall (Diez-Fernández et al., 2023). In addition, psychological factors such as concentration, courage, and emotional control also play an important role in determining an athlete's performance during a competition (Rahmawati et al., 2025). Thus, developing physical abilities such as hand grip strength is an important aspect in developing rock climbing athletes so that they can achieve optimal performance (Aliriad et al., 2023).

Strength is the ability of muscles to overcome a load through muscular effort, as demonstrated by pulling, lifting, and pushing the body while in a suspended position (Adinda Az-Zahra et al., 2024). However, in athlete coaching practice, monitoring handgrip training is often subjective based on the coach's observations, preventing accurate measurement of athlete development. This situation has the potential to lead to inaccurate training load management and increases the risk of fatigue and decreased athlete performance. Furthermore, limitations in the use of monitoring technology make it difficult for coaches to obtain objective data on athlete development during training (Rafi Tri Indarwan & Adi S, 2025). Along with advances in science and technology, the use of Internet of Things (IoT)-based wearable devices is increasingly being applied in competitive sports. IoT technology enables electronic devices to automatically record various parameters of an athlete's physical activity and transmit this data in real time (Yuwono et al., 2025). In addition, developments in sports technology also enable the use of digital devices to assist in the process of monitoring training and analyzing athlete performance more effectively (Mundry et al., 2021). Although the development of wearable technology has been widely applied in various sports, the use of monitoring technology specifically for handgrip strength training in rock climbing is still relatively limited, especially in regional athlete development (Soenyoto et al., 2025).

Based on the results of initial observations on rock climbing athletes in Semarang City, handgrip training has been carried out routinely using methods such as hangboards and fingerboards, but the training evaluation process has not been supported by an integrated technology-based monitoring system (Tommy Soenyoto et al., 2024). This condition indicates a gap between the need for sports science-based sports development and training practices that are still carried out conventionally in the field (Syahril Akram, Muh. Adnan Hudain, Saharullah , Andi Ridwan, 2025). The integration of technology into the training process is expected to increase the objectivity of training load control and provide accurate feedback to coaches and athletes (S et al., 2021). The novelty of this research lies in the development of a handgrip strength training module integrated with a Smart IoT Bracelet device as a training monitoring system. The developed training module not only contains a systematic handgrip training program, but is also equipped with a technology-based monitoring system that supports more accurate and measurable training evaluation. Based on the problem identification, research gaps, the urgency of implementing technology in training, and the novelty offered, the purpose of this study is to develop a Smart IoT Bracelet-based handgrip strength training module that is suitable for use in the training process of rock climbers. In addition, this study also aims to determine the level of module feasibility based on expert assessment and test the effect of using the module on increasing the handgrip strength of rock climbers.

2. Method

This study employed a Research and Development (R&D) methodology. The product developed was a handgrip training module based on a Smart IoT Bracelet, which can be used as a training guide and a tool for monitoring the handgrip strength of rock climbers. This study was conducted on rock climbers in Semarang City under the guidance of the Semarang City Rock Climbing Forum, which was divided into three locations: the Jatidiri Sports Center, the Tri Lomba Juang Sports Center, and the Semarang City FPTI Secretariat in Kedung Mundu. The research locations were selected based on the consideration that Semarang City has a large number of rock climbers who actively participate in various championships and have a structured training program. The data sources in this study consisted of primary data obtained directly from athletes and coaches through observation, interviews, and questionnaires used to assess the developed training module, as well as data from handgrip strength measurements using the Smart IoT Bracelet during training. The research stages included needs analysis, product design, product development, expert validation, product trials, and product revision. The resulting product is a structured handgrip training module integrated with an IoT-based system capable of recording grip strength and duration in real time. The data obtained from the questionnaires were first tested for validity and reliability to ensure the instrument used was appropriate and consistent in measuring the research variables. Next, the handgrip strength measurement data were analyzed using normality and homogeneity tests to determine whether the data were normally distributed and had equal variance. After meeting the analysis requirements, the data were then analyzed using a t-test to determine the difference in handgrip strength results before and after using the developed training module. The results of this data analysis were used to determine the feasibility and effectiveness of the developed Smart IoT Bracelet-based handgrip training module.

3. Result

This study aims to determine the effectiveness of using a handgrip strength training module on improving the grip ability of rock climbers. Data collection was conducted by measuring handgrip strength before and after using the training module during a predetermined training period. Handgrip Strength Measurement Results Before and After Module Use Handgrip strength measurements were conducted on all athletes in the study sample. Measurements were taken twice: before using the training module (pretest) and after using the training module (posttest). The results indicated an improvement in handgrip strength after using the training module.

Table 1. Tests pf normality

Tests of normality				
Handgrip		Shapiro-wilk		
		Statistic	df	Sig.
Results	Right Hand Pretest	0,965	10	0,846
	Left Hand Pretest	0,958	10	0,759
	Posttest Right Hand	0,948	10	0,646
	Posttest Left Hand	0,865	10	0,088

Based on the results of the normality test using the Shapiro-Wilk method, it was found that all handgrip strength measurement data, both in the pretest and posttest for the right and left hands, had significance values (Sig.) greater than 0.05.

Table 2. Test of normality

Tests of normality				
Explosive dynamics		Shapiro-wilk		
		Statistic	df	Sig.
Results	Initial Right Treatment	0,928	10	0,425
	Initial Left Treatment	0,941	10	0,563
	Final Treatment Right	0,869	10	0,096
	Final Treatment Left	0,880	10	0,129

Based on the results of the normality test using the Shapiro-Wilk method, it was found that all data for the explosive strength variable (explosive dynamics) in the treatment group, for both the initial and final measurements for the right and left hands, had a significance value (Sig.) above 0.05.

Table 3. Test of homogenecity of variance

Test of homogeneity of variance					
		Levene statistic	df1	df2	Sig.
Results	Based on Mean	0,371	3	36	0,775
	Based on Median	0,346	3	36	0,792
	Based on Median and with adjusted df	0,346	3	34,592	0,792
	Based on trimmed mean	0,369	3	36	0,776

Based on the results of the test for homogeneity of variances using Levene's test, the significance values (Sig.) for several approaches were obtained: 0.775 based on the mean, 0.792 based on the median, 0.792 based on the adjusted median with degrees of freedom, and 0.776 based on the trimmed mean. All significance values were above the 0.05 threshold. This indicates that the data variance across groups is homogeneous or equal.

Table 4. Paired samples test

Paired samples test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair 1	Pre Test Handgrip - Post Test Handgrip	-2,481	2,309	0,516	-3,562	-1,400	-4,804	19	0,000

The analysis results showed a difference between the handgrip pre-test and post-test scores. The mean difference was -2.481, indicating a higher post-test score than the pre-test (an improvement after treatment). The t-test value of -4.804 with df = 19 and a significance value of Sig. (2-tailed) = 0.000 (<0.05) indicates that the difference between the pre-test and post-test was statistically significant.

Table 5. Paired samples test

Paired samples test									
		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair 1	Pre treatment-Post treatment	-9,682	5,258	1,176	-12,142	-7,221	-8,234	19	0,000

The analysis results showed a significant difference between the initial and final treatment scores. The mean difference was -9.682, indicating that the post-treatment (final) scores tended to be higher than the pre-treatment (initial) scores. The t-test value of -8.234 with df = 19 and a significance value (Sig. (2-tailed) = 0.000) less than 0.05 indicates that the difference is highly statistically significant.

Table 6. Variable test

Dinamis Eksplosif	Total	r table
T01	0,616	0,361
T02	0,559	0,361
T03	0,798	0,361
T04	0,705	0,361
T05	0,482	0,361
T06	0,405	0,361
T07	0,361	0,361
T08	0,453	0,361
T09	0,913	0,361
T10	0,916	0,361
T11	0,975	0,361
T12	0,954	0,361
T13	0,974	0,361
T14	0,948	0,361
T15	0,942	0,361

Dinamis Eksplosif	Total	r table
T16	0,948	0,361
TOTAL	1	0,361

The results of the validity test on the explosive dynamic variable show that all items have a calculated r value greater than or equal to the table r (0.361), so they can be declared valid. Items T01 to T16 generally meet the validity criteria, with correlation values ranging from 0.361 to 0.975.

Table 7. Reliability statistics

Reliability statistics	
Cronbach's Alpha	N of Items
0,949	16

Based on the reliability analysis results in the table, a Cronbach's Alpha value of 0.949 was obtained for 16 items. A Cronbach's Alpha value approaching 1 indicates that the research instrument has a very high level of internal consistency. This means that each item in the instrument is able to consistently measure the same construct.

4. Discussion

This study aims to determine the effectiveness of a hand grip strength training module based on a Smart IoT Wristband in improving the hand grip strength of rock climbing athletes. The results show a significant increase in hand grip strength after the athletes participated in a training program using the developed module. These results align with the study's objective, which emphasizes the importance of structured training supported by technology to enhance athletic performance (Diez-Fernández et al., 2023). The use of smart IoT wristbands helps coaches monitor training results in real time, allowing them to adjust the intensity of workouts based on the athletes' condition and reduce the risk of overexertion (Bahtiar et al., 2023). The use of IoT-based technology in sports training has also been reported to help improve the precision of workouts and support the development of more targeted training programs (Mundry et al., 2021).

The significant difference in results between the pretest and posttest scores indicates that the training module used was able to provide clearer exercise guidelines and help athletes train more consistently. Exercises performed routinely and in a structured manner can improve motor unit coordination and optimize the function of flexor muscles in the arms and fingers, thereby improving grip strength. These results align with research showing that structured training can enhance muscle strength more effectively than poorly planned or unstructured exercises (Sultan Brilin Susandi Eka Wahyudhi et al., 2023). Recent evidence shows that grip endurance is strongly associated with climbing success and fatigue resistance, particularly in high-intensity climbing activities (Baláš et al., 2021). However, the results of this study also reveal differences compared to some previous studies that focused solely on conventional handgrip training without technological integration.

The use of smart IoT wristbands in this study also helped coaches adjust training loads gradually based on data collected during training. This supports the application of the principle of

progressive overload, allowing muscles to adapt gradually and grip strength to improve over time. Additionally, the results of the validity and reliability tests indicate that the instruments used demonstrate good consistency, ensuring that the data collected is reliable and accurately reflects the athletes' actual performance levels (Rahmawati et al., 2025). These findings confirm that structured training supported by technological monitoring can enhance physical performance outcomes more effectively than conventional training methods alone. Overall, the results of this study provide strong evidence supporting the effectiveness of integrating structured training modules with IoT-based monitoring systems in sports training.

5. Conclusion and Recommendation

This study concludes that a hand grip strength training module based on a Smart IoT Bracelet is effective in improving the hand grip strength of rock climbers through structured and monitored training. The results indicate that the use of real-time monitoring technology helps improve training consistency and provides more objective data compared to manual monitoring. With data recorded in real time, coaches can monitor athletes' training progress more clearly and adjust training intensity as needed. The increase in hand grip strength observed in this study is also associated with neuromuscular adaptation, specifically an improvement in the nervous system's ability to activate muscles more effectively during exercise. Regular and controlled training helps the forearm muscles adapt gradually, allowing grip strength to increase optimally. This demonstrates that the use of technology-supported training modules not only facilitates more objective exercise monitoring but also supports the gradual improvement of athletes' physical capabilities. For future research, it is recommended that this module be tested over a longer training period for example, 12 sessions or 8 weeks and with a larger sample size. In addition, similar modules could be developed for other sports that require hand grip strength, such as archery, weightlifting, and rowing, thereby expanding the benefits of using technology in sports training.

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