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Physical capacity and performance correlation in sub-elite Indonesian archery athletes
Identificación de la capacidad física y su correlación con el rendimiento de los atletas de tiro con arco de sub-élite de Indonesia

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Abstract. The aim of this research is to analyse the physical components that can support the proper archery performance of young Indonesian athletes. This research employed a quantitative descriptive design involving 18 athletes from the East Java and West Java Archery Training Centre as the research subjects. Each athlete carried out a physical test consisting of 9 physical test items (1' incline sit up, Bosy Right, Bosy Left, MFT, Hover, Superman Back Hold, Pinch Grip, standing balance test, standing archery hold), which the trainer has prepared according to the needs of archery. After that, archery performance assessment was done using the recurve division's individual qualification system, i.e., arrow athletes performed 72 arrow shots. The data were then analysed using descriptive tests, silhouette method tests, and K-means clustering analysis to classify physical components and simplify the data collection process. These processes increased the accuracy of changes needed in the training process to improve athlete performance. A correlation test was also conducted using a Spearman's rho with a significance $p<0.05$. The study's results revealed that the silhouette method divided the variables into six clusters. The K-means cluster analysis results showed that exercises focused more on the arms, while trunk and lower extremity exercises received less attention. The research also found two physical aspects that had a positive and significant correlation with archery performance, namely, left pinch grip and right pinch grip. In addition, this research showed that the archers' physical aspects of pinch grip strength (left and right) were closely related to performance achievements or scores in archery.
Keywords: Physical capacity, sub-elite athletes, archery, archery performance.

Resumen. El objetivo de esta investigación es analizar los componentes físicos que pueden ayudar al rendimiento adecuado del tiro con arco de los jóvenes atletas indonesios. Esta investigación empleó un diseño descriptivo cuantitativo que involucró a 18 atletas del Centro de Entrenamiento de Tiro con Arco de Java Oriental y Java Occidental como sujetos de investigación. Cada atleta realizó una prueba física que constaba de 9 elementos de prueba física (sentadilla inclinada de 1', Bosy a la derecha, Bosy a la izquierda, MFT, Hover, Superman Back Hold, Pinch Grip, prueba de equilibrio de pie, agarre de tiro con arco de pie), que el entrenador había preparado de acuerdo con las necesidades del tiro con arco. Después de eso, se realizó la evaluación del rendimiento del tiro con arco utilizando el sistema de calificación individual de la división recurva, es decir, los atletas de flecha realizaron 72 tiros de flecha. Luego, los datos se analizaron utilizando pruebas descriptivas, pruebas del método de la silueta y análisis de agrupamiento de K-means para clasificar los componentes físicos y simplificar el proceso de recopilación de datos. Estos procesos aumentaron la precisión de los cambios necesarios en el proceso de entrenamiento para mejorar el rendimiento del atleta. También se realizó una prueba de correlación utilizando el coeficiente rho de Spearman con una significancia $p<0,05$. Los resultados del estudio revelaron que el método de silueta dividió las variables en seis grupos. Los resultados del análisis de conglomerados de K-means mostraron que los ejercicios se centraron más en los brazos, mientras que los ejercicios de tronco y extremidades inferiores recibieron menos atención. La investigación también encontró dos aspectos físicos que tenían una correlación positiva y significativa con el rendimiento en tiro con arco, a saber, el agarre de pinza izquierdo y el agarre de pinza derecho. Además, esta investigación mostró que los aspectos físicos de la fuerza de agarre de pinza de los arqueros (izquierdo y derecho) estaban estrechamente relacionados con los logros o puntuaciones de rendimiento en tiro con arco.
Palabras clave: Capacidad física, atletas de sub-élite, tiro con arco, rendimiento en tiro con arco.

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Introduction

Physical capacity is essential for achieving success in achievement sports (Ranković et al., 2010). Good physical quality allows athletes to acquire specific technical skills (Bafirman & Wahyuri, 2019). Research has investigated that physical capacity is one of the main contributors to supporting skills in most sports (Malm et al., 2019; Xu, 2015), including archery (Rizal et al., 2023). Archery, an enduring sport that has fascinated athletes for years, demands a certain blend of physical qualities and abilities that can be difficult to recognize and evaluate (Gargoum, 2019; Lau et al., 2020a; Setyawan et al., 2024; Yachsie et al., 2024). In archery, movement encompasses several stages, including stance, set, setup, drawing, anchoring, aiming, release, and follow-through. These stages require high physical capacity because the athletes need to keep their movements stable. Any instability adversely affects the outcomes of the ultimate arrow release (Handayani et al., 2024). Thus, scholars agree that it is necessary to maintain physical conditions to support concentration and accuracy in archery (Prasetyo et al., 2020).

One of the ways to do so is through physical training. Physical training must be carried out in a structured, organized, and programmed manner so that there is a good increase in physical abilities (Nasrulloh et al., 2022). Although it will not directly affect the mastery of specific technical skills, physical capacity will reduce the rate of movement errors, especially during high-intensity training sessions, thereby reducing the risk of injury (Bompa & Buzzichelli, 2015; Puspitasari, 2019). The connection between physical capacity and archery shooting performance is not well understood, despite physical abilities being recognised as crucial for sports performance. Exploring this relationship is anticipated to help pinpoint the fitness elements that enhance performance. Soylu et al. (2006) emphasised that archery combines both aerobic and anaerobic movements. Archers dedicate significant time to practicing and competing at the archery range (Lau et al., 2020b). They must walk to the target area 12 times to assess their score and collect the arrows, which are located 70 metres away (Sergiy et al., 2017). In addition to sufficient aerobic capacity, archers need strong muscles in the arms, chest, shoulders, and back to perform the repetitive action of drawing the bowstring (Tinazci, 2011). Recent advancements in computer technology have led scholars to use artificial intelligence to forecast archery performance by analysing physical fitness components (Muazu Musa et al., 2019). Research indicates that archers' performance can be categorised based on their upper body strength, endurance, balance, and power, highlighting the importance of these physical attributes in achieving optimal performance.

While physical capacity is widely recognized as crucial for archery performance, the challenge lies in developing accurate and reliable methods to assess and enhance this capacity, particularly in preparation for high-level competition. In archery, the preparatory stage always begins with the formation of physical capacity according to the needs of the sport (Bafirman, 2010; Harsono, 2018). Athletes must increase their physical capacity before entering the specialized preparation stage because the primary physical condition must peak in a special preparation. Unfortunately, current physical capacity tests do not reflect the actual physical capacity conditions that can accurately help improve the performance of archery athletes. Currently, the evaluation method for testing the physical capacity of archery athletes is still very subjective and does not use quantitative and qualitative analysis models. Therefore, creating a physical exercise test model with high accuracy and minor errors is a challenge that needs to be solved.

The key to the success of the archery athlete's physical test is to describe the impact of physical training, which has a full role in training and competition performance (Susanto et al., 2021). However, the physical capacity test formulation lacks an effective evaluation method, primarily a comprehensive evaluation method, which makes the test implementation unable to run smoothly. Based on the background and reasons mentioned above, this article argues that continuous improvement in finding the correct physical test item formulations for archery athletes is necessary. It proposes an evaluation model for archery for all physical tests based on the k-mean clustering algorithm, addressing the need for a more accurate and reliable method to evaluate physical capacity in archery athletes.

The current archery physical capacity test has several shortcomings that merit further examination. One of the primary issues is the lack of consideration for the impact of environmental factors, such as wind and weather conditions, on an archer's performance. As noted in a study using principal component analysis to identify key physical fitness components in youth archers, archers must "take the wind, downpour, or other climate conditions into consideration while shooting every arrow at the recommended period (Eswaramoorthi et al., 2018). This suggests that the current test may not adequately assess an archer's ability to perform under the varying environmental conditions they may face during competition.

In this field, research has focused on exploring the physical characteristics and performance factors contributing to successful archery. One study found that various anthropometric measurements, such as height, weight, and arm range, as well as kinesthetic perception tests, sit-and-reach, standing balance, and hand dynamometer, can provide valuable insights into an individual's potential for archery (Lau et al., 2020a; Prasetyo et al., 2022). Another study compared the anthropometric and physical fitness components between high- and low-performance archers, highlighting the importance of factors like body composition, muscular strength, and endurance in archery performance (Musa et al., 2016, 2019; Y. Prasetyo et al., 2022). In Pakistan, researchers have also investigated the use of principal component analysis to pinpoint the crucial physical fitness elements required for proficient archery (Sobko et al., 2019). This technique enables researchers to identify the underlying factors that contribute to overall physical fitness, thereby facilitating talent identification and training programs for aspiring archers. While the existing research provides a solid foundation for understanding the physical demands of archery, further investigation is needed to develop more comprehensive and reliable methods for identifying the key physical components of archery athletes.

Methods

Study Design

This research employed a descriptive quantitative approach. The research aimed to identify the physical factors associated with archery performance in Indonesian sub-elite athletes.

Subjects

The study involved 18 archery athletes as research subjects. These subjects were currently undergoing training in regional camps located in East Java and West Java, Indonesia. The participants in this study were adolescents between the ages of 13 and 14, consisting of 7 males and 6 females. On average, they had been practicing archery for 7 years and had achieved national awards.

Instruments and Data collection

In order to collect data, this research utilized certain research instruments, such as physical tests. In this test, each athlete dealt with 10 physical test items (1' incline sit up, MFT (Multi Fitness Test), Hover, Superman Back Hold, Pinch Grip, one leg balance test, standing archery hold) that the trainer has prepared according to the needs of archery.

The 1'-incline sit-up test aims to determine abdominal muscle strength. The test item was done by performing the 1' incline sit-up test for 30 seconds and then calculating the number of repetitions possible. This item was followed by the hover. It is a sort of plank test that aims to assess the control and endurance of the back and core stabilizing muscles. This test item began by assuming a position where the upper body was elevated off the ground using the elbows and forearms while the legs were extended and the weight was supported by the toes. The hip was elevated from the floor, resulting in a perfectly aligned position from the head to the toe. Once the subject was in the appropriate position, the stopwatch was initiated. The head should be oriented downward and not directed forward. The test concluded when the research subjects could not maintain a straight back and lower their hip.

The Superman Back Hold aims to gauge the strength of the lower back muscles. To conduct this test, this research assumed a supine position with the head in a neutral alignment. The arms must be fully extended forward while the muscles were activated to maintain core stability. In addition, subjects' upper limbs and lower limbs were elevated simultaneously while contracting their gluteal and lumbar muscles. They must ensure the alignment of the head and body during the entire action. They were regarded to pass this test if they could hold the Superman Back in just a few seconds.

After that, the pinch grip test was conducted to assess the isometric peak strength of the hand and forearm muscles when performing pinch movements. This test is similar to the hand grip strength test but specifically measures finger pinch strength. In this research, the procedure began by carrying out the drawing technique of drawing an arc with both right and left hands. The athletes (subjects) used the finger draw technique. This test measured the athlete's ability to hold the draw in the correct starting position, calculated in seconds.

The pinch grip test was then followed by the one-leg balance test. The purpose of this test is to assess the overall equilibrium of the entire body. In this research, particularly, the objective was to observe if the subjects could maintain a uni pedal stance for the maximum duration possible. The test began by having participants elevate either their right or left foot from the ground, initiating the timing process. The timing stopped when the raised foot made contact with the ground or when the individual jumped or otherwise left their stable stance. Time refers to the subjects' overall duration for which a person may maintain a balanced position. The obtained value represents the maximum duration in seconds for which the person can maintain stable equilibrium.

After that, the Arm Muscle Strength test is used to determine the strength of the archer's arm muscles when pulling the bowstring (Putra, 2022). The study utilized an EASTON handheld digital bow scale to accurately assess the strength of the arm muscles. When the subjects exerted their maximum effort to draw the string, the bow scale would display a numerical value that represented the muscle's strength. The weight was quantified in kilograms. Meanwhile, MFT was carried out to determine the subjects' fitness by running back and forth for 20 meters. The MFT assessment used the subject's achievement level and shuttles the test results, which were then converted into a VO2 Max value in ml.kg-1.min-1 units (Paradisis et al., 2014).

Having collected data on subjects' physical capacity, this research gathered other data related to subjects' performance in archery. The data was collected using the recurve division's individual qualification system, where each archer shot 72 arrows at an archery target at a distance of 70 metres (Kolayis et al., 2014).

Statistical analysis

Data analysis was carried out by classifying physical test results with K-means analysis using R studio software to ensure the accuracy of the archery test results and simplify the data collection process. The K-means classification is based on the sum of the results of the squared clustering errors. This research also used the similarity assessment method for the Euclidean distance. It is important to note that the standard K-means classification faces issues with significant P central deviation and inconsistency across sample types, affecting the result accuracy. To address this issue, a Spearman's rho correlation test was conducted to examine physical aspects and archery performance.

Results

This study aims to classify archery athletes' physical profiles based on the types of physical tests used by the coaches. The analysis seeks to categorize these profiles and assess their impact on archery performance. The descriptive test results are described in Table 1.

Table 1.
Descriptive test results

No	Variables	Mean±SD
1	Sit Up	24.22±6.31
2	HF (sec)	105.44±23.35
3	SBR (sec)	84±13.82
4	SBL (sec)	84.67±16.18
5	SBH (sec)	53.28±7.46
6	Arm Muscle Strength (kg)	15.47±3.25
7	PG ki (sec)	77.22±13.59
8	PG ka (sec)	85.17±8.81
9	MFT (ml.kg-1.min-1)	27.4±2.10
10	Archery Performance (score)	619.61±22.22

Note: HF = Hover Front, SBR = Standing Balance Right, SBL = Standing Balance Left, SBH = Superman Back Hold, PG.Ki = Left Pinch Grip, PG.Ka = Right Pinch Grip, MFT = Multi Fitness Test

To facilitate a comprehensive analysis, the physical test data were processed through data entry and transformed to align with the analysis assumptions. The results of this data transformation are presented in Table 2.

Table 2.
Data Transformation Results

No	Sit-up	HF	SBR	SBL	SBH	Arm Muscle Strength	PG.Ki	PG.Ka	MFT
1	0.59859	1.30833	0.43408	0.32972	-1.37806	0.62363	-0.89944	-1.38152	-0.47680
2	-0.35211	0.62324	-2.31508	0.32972	-1.10990	-0.91409	0.57237	0.54882	0.81055
3	0.75750	-1.00385	0.43408	0.32972	0.90132	0.62363	0.94032	0.54882	-0.28608
4	-0.66902	0.62324	0.43408	0.20607	0.90132	0.62363	0.94032	0.54882	1.90718
5	-0.66902	0.62324	0.43408	0.32972	0.90132	-0.14523	0.20442	0.54882	-0.28608
6	0.12324	-1.38921	0.43408	-3.68870	0.90132	-0.91409	-0.16353	-0.01893	-1.04895
7	-1.30282	-1.94585	0.43408	0.32972	0.49908	-0.91409	-1.85611	-2.85766	0.81055
8	0.12324	0.62324	0.43408	0.32972	0.90132	1.70003	0.13083	0.54882	-2.00254
9	2.34155	-1.38921	0.43408	0.32972	-1.91438	-1.06786	0.94032	0.54882	-1.04895
10	0.12324	1.05142	0.43408	0.32972	-0.03725	0.62363	0.20442	-0.58667	1.52574
11	0.91549	0.66606	-2.02570	0.26789	0.23092	-0.91409	-0.16353	0.54882	0.09536
12	-0.19366	0.88015	0.43408	0.32972	-0.97581	-0.91409	-1.85611	0.54882	-0.28608
13	-0.51056	-0.78976	0.43408	0.26789	-1.37806	1.39249	0.94032	0.54882	0.28608
14	-0.66902	0.40915	0.43408	0.32972	0.09684	0.77740	0.20442	0.54882	-0.09536
15	0.12324	-0.62324	-2.17039	-1.33947	0.90132	-0.60655	-1.85611	-0.01893	0.28608
16	-1.61972	-0.70412	0.43408	0.32972	0.90132	-0.91409	-0.91409	-1.72216	-1.23967
17	-0.82747	-0.83257	0.43408	0.32972	0.63316	1.70003	0.94032	0.54882	1.14431
18	1.70775	0.62324	0.43408	0.32972	-0.97581	-0.76032	0.94032	0.54882	-0.09536

Note: HF = Hover Front, SBR = Standing Balance Right, SBL = Standing Balance Left, SBH = Superman Back Hold, PG.Ki = Left Pinch Grip, PG.Ka = Right Pinch Grip, MFT = Multi Fitness Test

After data transformation was carried out, the data was then classified into a number of similar clusters. Figure 1 illustrates the distribution of clusters in the athlete's physical profile data using the silhouette method.

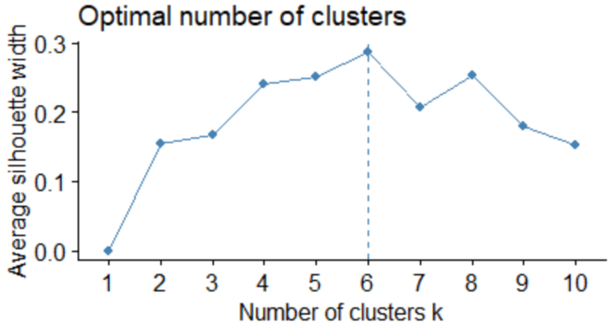

Figure 1. The number of clusters.

Based on the graph in Figure 1, the data are divided into 6 clusters. As presented in Table 3, the following details the result of this division into 6 clusters:

Table 3.
Final Cluster Results

No	Sit-up	HF	SBR	SBL	SBH	Arm Muscle Strength	PG.Ki	PG.Ka	MFT	Final Cluster
1	0.5986	1.30833	0.43408	0.32972	-1.37806	0.62363	-0.89944	-1.38152	-0.47680	5
2	-0.3521	0.62324	-2.31508	0.32972	-1.10990	-0.91409	0.57237	0.54882	0.81055	1
3	0.7575	-1.00385	0.43408	0.32972	0.90132	0.62363	0.94032	0.54882	-0.28608	2
4	-0.6690	0.62324	0.43408	0.20607	0.90132	0.62363	0.94032	0.54882	1.90718	2
5	-0.6690	0.62324	0.43408	0.32972	0.90132	-0.14523	0.20442	0.54882	-0.28608	2
6	0.1232	-1.38921	0.43408	-3.68870	0.90132	-0.91409	-0.16353	-0.01893	-1.04895	6
7	-1.3028	-1.94585	0.43408	0.32972	0.49908	-0.91409	-1.85611	-2.85766	0.81055	4
8	0.1232	0.62324	0.43408	0.32972	0.90132	1.70003	0.13083	0.54882	-2.00254	2
9	2.3416	-1.38921	0.43408	0.32972	-1.91438	-1.06786	0.94032	0.54882	-1.04895	3
10	0.1232	1.05142	0.43408	0.32972	-0.03725	0.62363	0.20442	-0.58667	1.52574	2
11	0.9155	0.66606	-2.02570	0.26789	0.23092	-0.91409	-0.16353	0.54882	0.09536	1
12	-0.1937	0.88015	0.43408	0.32972	-0.97581	-0.91409	-1.85611	0.54882	-0.28608	5
13	-0.5106	-0.78976	0.43408	0.26789	-1.37806	1.39249	0.94032	0.54882	0.28608	2
14	-0.6690	0.40915	0.43408	0.32972	0.09684	0.77740	0.20442	0.54882	-0.09536	2
15	0.1232	-0.62324	-2.17039	-1.33947	0.90132	-0.60655	-1.85611	-0.01893	0.28608	1
16	-1.6197	-0.70412	0.43408	0.32972	0.90132	-0.91409	-0.91409	-1.72216	-1.23967	4
17	-0.8275	-0.83257	0.43408	0.32972	0.63316	1.70003	0.94032	0.54882	1.14431	2
18	1.7078	0.62324	0.43408	0.32972	-0.97581	-0.76032	0.94032	0.54882	-0.09536	3

Note: HF = Hover Front, SBR = Standing Balance Right, SBL = Standing Balance Left, SBH = Superman Back Hold, PG.Ki = Left Pinch Grip, PG.Ka = Right Pinch Grip, MFT = Multi Fitness Test

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To simplify the K-means clustering analysis process, cluster data is presented in plot forms as illustrated in Figure 2:

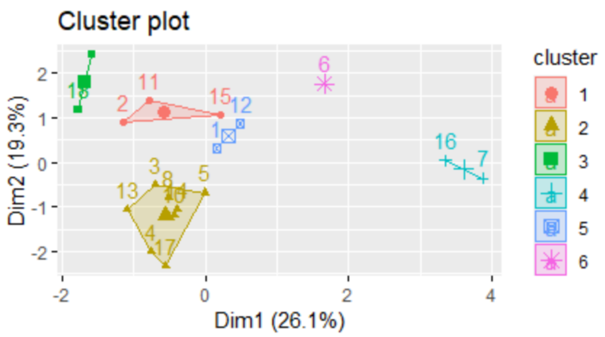

Figure 2. Graph of the results of the distribution of the number of clusters.

Based on data from the physical test results of the East Java and West Java Archery athletes in 2021, 9 variables were found out of 18 athletes. Before the K-means clustering test was carried out, data transformation was conducted first to convert the scale of data measurement into another form to meet the assumptions of the analysis. After the data was transformed, an analysis was performed to determine the recommended number of clusters. Then, using the silhouette method, the analysis results showed 6 clusters. Next, a K-Means clustering analysis was done by dividing the data into 6 clusters. The results were athletes coded as A2, A11, and A15 were placed in Cluster 1. Meanwhile, A3, A4, A5, A8, A10, A13, A14, and A17 were grouped in Cluster 2. While A9 and A18 were in Cluster 3, A7 and A16 were placed in Cluster 4. Then, A1 and A12 were placed in Cluster 5, and A6 was put in Cluster 6.

Cluster division was carried out through K-Means Clustering analysis, which was further strengthened by a description of the characteristics of the test results for each individual in each cluster. The results of the characteristic description of the test results for each cluster are presented in Table 4:

Table 4.
Descriptive test results

No	Cluster	Characteristic	Athlete's code
1	Cluster 1	Highest sit-ups, HF was 2nd, and the values of SBL, MFT, Arm Muscle Strength, right PG, and left PG were 3rd.	A2, A11, A15
2	Cluster 2	Lowest sit-ups (2^{nd}), the values of HF, SBH were 3^{rd}. SBR, Arm Muscle Strength, right PG, and MFT ranked 1^{st}, while SBL and left PG rank 2nd.	A3, A4, A5, A8, A10, A13, A14, A17
3	Cluster 3	Highest sit-ups, SBR, SBL, left PG (1^{st}). HF ranked 4th, lowest SBH, Arm Muscle Strength, Right PG and MFT were 3rd.	A9, A18
4	Cluster 4	The lowest sit-ups and left PG, 2^{nd} lowest HF 2, SBR, SBL were the 1st, SBH, Arm Muscle Strength, right PG, and MFT ranked 2nd.	A7, A16
5	Cluster 5	Sit-ups ranked 3rd, highest HF, SBR, and SBL. Lowest SBH and left PG (2^{nd}), Arm Muscle Strength, right PG, and MFT were 2^{nd}.	A1, A12
6	Cluster 6	Sit-ups were 3^{rd} lowest, HF, SBL, Arm Muscle Strength, Right PG, and MFT were the lowest, while SBR and SBH were highest.	A6

Note: HF = Hover Front, SBR = Standing Balance Right, SBL = Standing Balance Left, SBH = Superman Back Hold, Left PG = Left Pinch Grip, Right PG = Right Pinch Grip, MFT = Multi Fitness Test

In Cluster 1, three athletes ranked the second largest after Cluster 2. The physical profile characteristics of athletes in this group were generally good. They had the highest number of sit-ups, ranked 2nd in the Hover Front test, and ranked 3rd in standing balance left, Multistage Fitness Test (MFT), Arm Muscle Strength, right Pinch Grip, and left Pinch Grip most was number 3. This balance between the physical profiles of the lower and upper extremities supports posture and stability during archery, making it an ideal shape for archers.

Following the analysis of Cluster 1, athletes were partly distributed in Cluster 2, which showed a distinct profile. This group had the lowest number of sit-up scores but the highest Hover Front and Superman Back Hold scores (ranked 3^{rd}). They also ranked 1^{st} in standing balance right, Arm Muscle Strength, Pinch Grip Right, and the best MFT. Additionally, they ranked 2^{nd} in a left pinch grip. Based on these characteristics, Cluster 2 showed good physical test results in muscle strength and endurance, particularly in the arms, and good heart-lung capacity. However, this group showed lower abdominal muscle strength. The cluster analysis indicated that there was an imbalance between exercises that support posture and bow stability. Most of the high scores were components related to bow stability, while the strength and endurance of the torso were still not yet optimized.

Cluster 3 consists of two athletes with specific physical profile characteristics. They ranked 1^{st} in sit-ups, right side left side, and left pinch grip. However, they ranked 4 in the Hover Front test and had the lowest score in Superman Black Hold (SBH). Additionally, they ranked 3^{rd} in Arm Muscle Strength, Right Pinch Grip, and MFT. The cluster analysis indicated that balance between exercises supporting posture and bow stability had not been achieved. Most high scores were related to posture stability, while the two parts of the muscles that support bow stability were still low.

Cluster 4 consists of two athletes with the lowest scores in sit-ups and Left Pinch Grip and the 2^{nd} lowest in the Hover front test. However, they ranked 1^{st} in Standing Balance Right and performed well in Standing Balance Left. For SBH, Arm Muscle Strength, Right Pinch Grip, and MFT, they ranked 2nd. The cluster analysis showed that the balance between exercises supporting posture and bow stability had not been achieved. Most of the high scores were related to bow stability, while the strength and endurance of the torso remained low.

The physical profile characteristics of athletes in Cluster 5 showed strong performance in several areas. They 3rd in sit-ups number 3, 1st in HF, SBR, and SBL, but had the lowest score in SBH and ranked 2nd in Left PG, Arm Muscle Strength, right PG, and MFT. These test results suggest an imbalance between the readiness of muscles supporting posture stability and bow stability. In particular, the physical components supporting bow stability, such as arm flexibility, showed lower results.

The physical profile characteristics of athletes in Cluster 6 showed the lowest scores in sit-ups (ranked 3rd), HF, SBL, Arm Muscle Strength, Right PG, and MFT. They also had the lowest scores in SBR but ranked highest in SBH. The analysis of this cluster indicates a low level of fitness, with weak strength and endurance in the muscle-supporting posture and bow stability.

Table 5.
The correlation between physical aspects and archery performance

No	Physical aspects	Correlation of spearman's rho	
		r	p-value
1	Sit Up	0.044	0.862
2	Hover Front (HF)	0.053	0.834
3	Bosy Right (BR)	-0.084	0.740
4	Bosy Left (BL)	0.174	0.490
5	Superman Back Hold (SBH)	-0.150	0.553
6	Standing Archery	0.445	0.064
7	Left Pinch Grip (PG.Ki)	0.632	0.005*
8	Right Pinch Grip (PG.Ka)	0.748	0.000*
9	Multistage Fitness Test (MFT)	0.281	0.258

*p<0.05= there is a significant relationship with archery performance

As argued earlier, Spearman's rho correlation test was conducted to address issues regarding central deviation and result consistency. Table 5 above shows that there are two physical aspects that have a significant correlation with archery performance, namely Left Pinch Grip ($p<0.05$) and Right Pinch Grip ($p<0.05$). These two aspects also show a positive correlation to archery performance. The results of this study are consistent with the results of research conducted by Lau et al. (2020). In their research, one of the physical components that affect performance in archery is the right-hand grip. The stronger the archer's right handgrip leads to a higher score in archery. This is related to the needs in archery because when pulling the bow back, the archer pulls the weight of the bowstring, ranging from 14 to 22 kg. Hence, in one tournament, arrow athletes can bear a load of up to 1,440 kg in shooting 72 arrows (Sezer, 2017). Research conducted by Suppiah et al. (2017) also concluded that in archery, the strength of the archers' hand grip is a very important variable.

Discussion

A number of coaches and sports scientists have recognized the importance of measuring the physical status of athletes. These data are often used to help the coaches prepare training programs. The coaches will carry out a series of physical tests that are deemed necessary and essential to support their sport (Ismaryati & Muhyi, 2018; Sepdanius et al., 2019). The types of physical tests conducted by the coach and his team are often based on traditional habits. This limits the scope of the physical profile analysis because the same tests are repeated without introducing new methods, leading to a lack of progress or development in the analysis. The process of formulating athletes' physical test components and instruments should be carried out with a combination of two factors: reviewing the literature related to tested physical tests and conducting an analysis of factual data related to physical components that contribute to improving archery performance.

Archery is a sport that requires reasonable movement control, and postural stability is considered an essential variable for achieving high performance (Sarro et al., 2021; Wada & Takeda, 2020). In order to better understand the harmony between the archer and the bow during the aiming phase, it is necessary to have postural control in recurve archery in terms of shooting performance. The results showed that the synchronization between body sway and bow sway could affect shot accuracy, which indicates an essential combination between balance training and bow stability (Sarro et al., 2021; Spratford & Campbell, 2017). Producing a perfect shot requires posture and bow stability. Body posture is maintained so that it does not sway much in a standing position, as both legs must support the torso, while the torso must be strengthened to support the aiming position carried out mainly by the arms. Postural balance has the characteristics of non-locomotor movements with isometric contraction types. Exercise with this type of contraction will support archery performance. On the other hand, posture and bow stability are affected by the strength and endurance of the muscles involved.

When drawing a bow, the activity of the humerus/scapula/shoulder muscles increases to maintain stability in the aiming position. This increase in shoulder muscle capacity will affect stability while aiming. Although the strength required for archery can be obtained from the humerus or scapula muscles in the full draw position, the amplitude of the scapular muscles plays an essential role in stabilizing the movement by reducing humeral tremor (Lin et al., 2010).

The strength and endurance of an archer's arm muscles also determine the choice of the right bow. Coaches must understand each athlete's muscle strength and arm endurance to ensure a proper match (Prasetyo et al., 2022). These variables are key contributors to archery performance and can serve as important indicators for identifying potential archers and evaluating archer performance. By focusing on the essential variables, the time needed to develop archers into expert archers can be shortened (Saleh et al., 2022). Strong arm muscles play a significant role in bow stability, requiring less energy to maintain the aiming position for a longer period. Low muscle activity increases performance precision and delays muscle fatigue, resulting in sustained performance during competitions (Clarys et al., 1990).

Shooting accuracy is influenced by postural balance and bow stability, though this connection is primarily observed at the individual level. Postural balance is directly and indirectly linked to shooting accuracy by enhancing bow stability. Because the role of postural balance appears to be important in shooting performance, the use of additional balance training programs to improve shooters' postural skills should be increased (Mononen et al., 2007).

The consistency of the final phase of a shot is essential to an archer's skill. Two types of movement can affect this consistency: tremors caused by fatigue and slow oscillations. Studies show that auditory feedback can reduce slow oscillations (Leroyer et al., 1993). Postural stability also depends on the activation and coordination of stabilizing muscles and maximum rocking speed. Muscle activation in both the upper and lower extremities occurs bidirectionally and ipsilaterally. Sixteen muscles, including vastusmedialis, medial hamstrings, tibialis anterior, and soleus, are engaged during maximum muscle effort. The relationship between bow stability and body stability is an important factor in an archer's performance (Zanevskyy et al., 2021).

On the other hand, no strong correlation was found between breathing parameters and the shooting performance of archers. However, it is believed that this association might increase with increased exercise levels and age (Bostanci et al., 2021). Two key factors that directly affect the shooting accuracy of shots in archery include postural stability and shoulder and arm muscle strength and endurance. Postural stability can be improved through balance exercises, related muscle strengthening, and endurance exercises. Similarly, the strength and endurance of the arm muscles are recommended to support the bow's stability, allowing the archer to aim more effectively.

Conclusion

The cluster analysis of the physical profiles of 18 young archery athletes divided them into six clusters. In all clusters, common characteristics were found, such as an imbalance between the quality of the muscles that support posture stability and those that support bow stability. Only 3 out of 18 athletes had a good balance of strength and muscle endurance, while the remaining 15 exhibited an imbalance between two muscle groups. Besides, the analysis revealed that the right pinch grip and the left pinch grip had a positive and significant correlation with arrow performance.

These findings indicate the need for a more balanced physical training regimen that equally targets the muscles supporting posture and bow stability. The k-means cluster analysis shows that current training focuses more on the arms and trunk, while lower extremity exercises receive less attention. This study also recommends focusing on grip strength, particularly the pinch grips, as they are strongly correlated with higher arrow scores. Stronger pinch grip strength leads to improved performance.

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