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How sport specialization age and training components influence the achievements of elite athletes

Novrizal Achmad Novan[1]*, Boyke Mulyana[1], Syifa Fakhomah Syihab[2], Nuryadi[3], Masayu Rizka Risjanna[1]

[1] Sport Coaching Department, Faculty of Sports and Health Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No.229, Bandung, 40131, Indonesia

[2] Nutrition Study Program, Faculty of Sports and Health Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No.229, Bandung, 40131, Indonesia

[3] Physical Education, Health, and Recreation Study Program, Faculty of Sports and Health Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No.229, Bandung, 40131, Indonesia

* Coressponding Author. E-mail: novrizal@upi.edu

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Abstract*:* Early specialization in sports for young elite athletes was undertaken for a variety of positive reasons, but it also can lead to increased vulnerability to injury, burnout, limited skill development, and negative effects on mental well-being as a result of intense training from a young age. The purpose of this study was to determine the relationship between age of sport specialization and training components to the achievements. This was a correlational survey and a cross-sectional approach to elite athletes in the city of Bandung. The sample for this study consisted of 84 high-level athletes who competed in 27 different sports and were eligible for athlete incentives from the government. Athletes were surveyed using a questionnaire to answer questions about their debut age, training frequency, duration, intensity, and highest championship achievement. The results of bivariate analysis showed that age, gender, age of specialization, duration of exercise, and intensity of exercise were not related to sports achievement. Based on the results of statistical analysis, it was known that the frequency of exercise was significantly correlated with sports achievement. Compared to athletes who train less than five times per week, athletes who train more than five times per week were found to have higher performance. Future possible research will assist in identifying the success factors of young athletes who begin sports specialisation at a young age.

Keywords: elite athlete, sport achievement, sport specialization, training frequency

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INTRODUCTION

Early sports specialisation is a trend in which athletes prioritise a single sport over all others and train for it year-round, frequently at the expense of other sports or hobbies (Murata et al., 2022). In recent decades, there has been considerable debate in the academic literature over the best time to begin specializing in a particular sport to improve sporting performance. The American Medical Society for Sports Medicine suggested early exposure to various sports and introduced a new definition for specializing in sports at a young age (N. Jayanthi et al., 2020). There has been a rise in injuries and health issues associated with early sports specialization in recent years, affecting both professional and amateur athletes. While the number of athletes who have chosen to specialise in a sport at a young age has risen dramatically over the last few decades (Padaki et al., 2017). According to new research, the inherent bias in favour of specialisation and intensive training is inherited from testimonials and empirical data from sporting authorities who hold outdated beliefs on the need for many years of training in sports (Spies et al., 2022). This lack of verifiable, practical evidence creates doubt over early sports specialization, prompting debates and inquiries into the origins and motivations behind this issue (Charbonnet & Conzelmann, 2024; Larson et al., 2023). However, the trend of early sports specialization continues to grow, leading to the establishment of numerous elite youth athlete programs. Young athletes are now reaching the elite level at younger ages than ever before. As young athletes progress from

amateur to professional levels, the number of young patients in sports medicine clinics has increased (Anderson et al., 2020). Consequently, many parties believe that unless their children engage in year-round participation in a single sport, they will be left out and their chances of success in that sport will diminish (Post et al., 2021). This negative social impact also hinders the intended goal of promoting early sports diversification.

A trend toward sport specialization can be observed by high-intensity, year-round training in a single sport at the exclusion of other sports (Waldron et al., 2020). Research on the factors that determine the incidence of specialization against diversification in different types of sports, such as the age of specialization, is also reported (Vaeyens et al., 2009)Click or tap here to enter text.In addition to variations in the quantity of deliberate play and training, it has been predicted that specialization leads to varied psychological effects, injury risk, and likelihood of burnout among athletes (Cobley et al., 2009; N. A. Jayanthi et al., 2019) Whereas when athletes have high self-efficacy related to the main concept in sports psychology, influencing an athlete's motivation, effort, and persistence will support their high level of performance in sports (Setiawan et al., 2020). Highly specialized athletes report significantly higher volumes of exercise-related training in the developmental period ages 6-12 and ages 13-15 during training (Gustafsson et al., 2007). Specialization in sports can thus be described as participation in a single sport with significant deliberate training and limited deliberate play. Sporting activities are generally segregated by age group to ensure all participants develop the necessary achievement-drive skills (Tribolet et al., 2019). The Long Term Athlete Development (LTAD) model (Balyi et al., 2013)and The Developmental of Sport Participation (DMSP) (Côté et al., 2012) categorize sports into two distinct periods: early (before age 12) and late specialization (after age 12). Previous studies have discovered that early exposure to a variety of physical activities and sports training as "deliberate play" and “learning to train” is essential for the development of elite athletes (Côté & Vierimaa, 2014). While deliberate play involves engaging in physically and mentally demanding activities that are intrinsically rewarding and deliver immediate gratification to facilitate enjoyment.

A substantial percentage of the expanding sports science and sports medicine literature defining words from the greatest popular athlete to a sedentary population has developed without a unified perspective or vocabulary for evaluating a specific training state and level. The term "elite" subjects may be one of the most overused and improperly utilized terms for the body of research pertaining to the discipline of exercise science (McAuley et al., 2022) The spectrum of terms like "trained," "highly trained," and "well-trained" seems subjective, depending on the participant's training load, training history, and training dedication (Decroix et al., 2016; Pauw et al., 2013). The range of athletes who can be considered "elite" or "expert" in a variety of sports was reviewed, and it was discovered that the range of this phrase comprised athletes competing at national-level contests up to athletes winning medals at major international competitions (Swann et al., 2015).

Even though longer periods of training are often connected with better levels of performance (Baker & Young, 2014), the time to reach the top in a sport varies greatly. In most sports, good performance takes 5–30 years to develop, and top athletes frequently peak between 15 and 40 years (Ericsson & Harwell, 2019). If we see athlete growth as a continual process of adaptation, then there will be a strong association between achievement and athlete age, especially given the relationship between training hours and age (Baker & Farrow, 2015). In addition to a winning mindset, factors such as height, weight, volume, intensity, the number of hours per week spent training, and years of experience in the specialized sport are also necessary for sporting success. For comparisons of athletes or factors like performance, a rigorous cohort definition is required. Numerous variables can explain training success, and levels of training can influence intervention results (McKay et al., 2022). This happened frequently in the context of sports, where the outcomes are mostly determined by the physical attributes, physiological condition, and motivation level of athletes to train independently (Fühner et al., 2021; Masanovic et al., 2020).

Therefore, this research takes it a step further than trying to understand the main and key things that can affect an athlete's performance specifically reviewed through the viewpoint of the athlete's training components that relate to their achievements. The purpose of this research was to investigate into the correlation between sports specialization age, gender, and exercise components: duration, frequency, and intensity towards sport achievement of elite athletes in Bandung.

METHODS

The study design included a correlational survey method and a cross-sectional approach. Purposive sampling was used in this study. This study included athletes who received achievement allowances from the city of Bandung and were willing to participate. Athletes who did not get an achievement allowance from the Bandung city government were unable to attend and complete the questionnaire were excluded. In this study, the dependent variable is the athlete's achievement as measured by participation at national and international competition levels; and the independent variables are the athlete's highest level of competition ever attended, gender, age of specializing in a specific sport, as well as the years, frequency per week, and intensity of training. The research was conducted on 84 athletes who received achievement allowances from the Bandung City government, and these athletes were considered as respondents in the study. These contributions include as many as 34% of Bandung athletes representing West Java at the 2021 National Sports Week (PON) and presenting 6.25% of Indonesia's total medal tally at the 2021 SEA Games in Vietnam (Brilyana, 2022; Prasatya, 2021). Data collection was performed simultaneously for 3 days from September 25-29, 2022, at the Indonesian National Sports Committee Office. Athletes are asked to sign informed consent independently for those aged over 18 years, while for those under 18 years old, the signing is done by parents or guardians. Athletes were requested to respond to a questionnaire that included research instruments. The questionnaire inquired about the age at which they began participating in sports, the frequency and duration of their training sessions per week and per day, the intensity of their training based on the periodization program, and their highest achievements in championships. All data on these variables were collected through questions contained in a self-administered research questionnaire. To identify the characteristics and achievements of athletes, a univariate analysis was carried out using STATA software version 17. In addition, a bivariate analysis was undertaken to determine the correlation between independent factors and athlete achievement. Independent variables with p-values <0.25 are considered to have a significant correlation with athlete's achievement.

RESULT AND DISCUSSION

Univariate Analysis

The Medical and Health Research Ethics Committee (MHREC) of the Faculty of Medicine, Public Health, and Nursing at Universitas Gadjah Mada has given their approval to carry out this study (approval number KE/FK/0809/EC/2022). Table 1 displays the respondent characteristics used in this study. The results of the univariate analysis revealed that 69 per cent of the respondents were teenagers. In this study, the number of male elite athletes was 51.2%, while the proportion of female elite athletes was 48.8%. There are currently equal opportunities for men and women to excel in sports.

Table 1. Respondents Characteristics and Description of Variable

Variables	(N)	(%)
Gender		
Men	43	51,2
Women	41	48,8
Age Group		
Teenager	58	69
Adult	22	26,2
Elderly	4	4,8
Specialization Stage		
Active Start	2	2,4
Fundamental	16	19
Learning to train	25	29,8
Training to train	25	29,8
Training to compete	16	19
Years of Training		
Short (5-10 years)	46	54,8
Long (>10 years)	38	45,2
Training Frequency (day/week)		
Low	48	57,1

High	36	42,9
Training Intensity		
Low	17	20,2
Moderate	46	54,8
High	21	25
Competition Attended		
Local	5	6
National	41	48,8
International	38	45,2
Achievement		
National	41	48,8
International	43	51,2

Another variable examined for this study is the age category. In general, athletes are divided into three age categories: teenagers (12 to 25 years), adults (26 to 45 years), and the elderly (46-65 years). In this study, the age of specialization was described based on LTAD categories, including active start (0-6 years), fundamental (6-8 years), learning to train (9-12 years), training to train (13-15 years), and training to compete (16-23 years) (Balyi & Hamilton, 2004). The use of categories in the LTAD is intended to identify the stage of athlete coaching. Using univariate analysis, it was calculated that 29.8% of athletes in the categories of learning to train and training to train participated in their first matches. Bandung has a high potential for producing outstanding athletes, as evidenced by a large number of high school-aged athletes. Although many of them are still in the learning-to-train and training-to-train stages, many have achieved national and international accomplishments.

The variable years of training are grouped into two distinct categories, namely short (5-10 years) and long periods (>10 years). This was adjusted to the average years of training of the sample athletes who responded to the study. The impact of sports training duration on the performance of young elite athletes is an important factor to consider when developing training programs. Understanding how different training durations can affect performance can help coaches and athletes tailor their approach for optimal results. Since the data are not normally distributed ($p=0.000$, $p<\alpha$), the cutoff point was set based on the median value (10 years). Univariate analysis showed that most respondents (54.8%) had trained for less than 10 years. Although the fact that these athletes have trained for less than ten years, their accomplishments have reached national and international levels. This study also examines the frequency of exercise, which is defined as the number of training days per week that athletes engage in. The calculation of median value was used since the distribution is not normal, thus a cutoff value of 5 is established. Most athletes (57.1%) train rarely (less than 5 days per week) since they are training on weekdays and rest on weekends. Low, moderate, and high-intensity variables were established for the exercise intensity variables. Low-intensity exercises emphasise dissociation, coordination, and laterality. Working memory, attentional network, inhibitory control, decision-making, and processing speed are needed throughout these tasks (Romero-Naranjo, 2022). Moderate-intensity exercise are typically associated with moderate-to-vigorous physical activity (MVPA) which can include exercises like brisk walking, cycling, swimming, or running that elevate heart rate and breathing (Gil-Rey et al., 2019). High-intensity activities involve exercises that specifically focus on improving physical conditions such as increased muscle power in the arms and legs, enhanced agility, and improved anaerobic endurance. An illustration of this can be seen in the demonstrated efficacy of high-intensity interval training (HIIT) in enhancing the power, agility, and endurance of athletes particularly during the special preparatory periodization stage (Festiawan et al., 2020). As much as 54.8% of athletes admitted to training with moderate intensity. At the time of data collection, the athletes were preparing for the upcoming West Java Regional Championship, which will take place in two months.

Athletes' achievements are grouped based on participation in national and international competitions. As many as 48.8% of athletes have participated in national-level competitions, both in the single-event and multi-event categories. The number of athletes who have participated in international championships is also not much different, namely 51.2%. Most of the athletes in this study, although still teenagers, have participated in championships at various levels of competition. This result demonstrate that Bandung's elite athletes are predicted to have the potential to achieve greater success over the years to come.

Bivariate Analysis

Using the chi-square test, the variables were further analyzed to determine the relationship between various factors and athletes' sporting achievements. Table 2 summarizes the results of the bivariate analysis.

Table 2. Relationship Between Identified Variable with Achievement of Athletes

Variables	Achievement		*P-value*	*OR*
	National	International		
Age Group				
Teenager	27 (32.1)	31 (36.9)	0.541	-
Adult	11(13.1)	11 (13.1)		
Elderly	3 (3.6)	1 (1.2)		
Gender				
Men	22 (26.2)	21 (25)	0.659	0.193
Women	19 (22.6)	22 (26.2)		
Specialization Stage				
Active Start	1 (1.2)	1.2 (1.2)	0.859	-
Fundamental	8 (9.5)	8 (9.5)		
Learning to train	10 (11.9)	15 (17.9)		
Training to train	14 (16.7)	11 (13.1)		
Training to compete	8 (9.5)	8 (9.5)		
Years of Training				
Short (5-10 years)	21 (25)	25 (29.8)	0.524	0.280
Long (>10 years)	20 (23.8)	18 (21.4)		
Training Frequency (day/ week)				
Low	29 (34.5)	19 (22.6)	0.014	1.116
High	12 (14.3)	24 (28.6)		
Intensity				
Low	6 (7.1)	11 (13.1)	0.259	-
Moderate	22 (26.2)	24 (28.6)		
High	13 (15.5)	8 (9.5)		

The bivariate analysis revealed no correlation between the athlete's age and their achievement, with a p-value = 0.541 ($p>0.05$). At the international level, 36.9% of teenage athletes competed, while 32.2% competed at the national level. Adult athletes who excel at both the national and international levels represent 13.1% of the total. Older athletes, on the other hand, are typically limited to national-level accomplishments. The findings indicate that teenage athletes play an important role in athletic achievement. This also demonstrates the ongoing process of sports development in teenagers. In addition, There was no correlation between the gender variable and the athlete's achievement, as indicated by the p-value of 0.659 ($p>0.05$). There is no gender difference among their national and international sporting achievements. Female athletes, on the other hand, have a higher chance of becoming senior elite athletes, as evidenced by their odds ratio of 0.193.

Moreover, the analysis also revealed that there was no correlation between the stage of specialisation and sports achievement, as indicated by the value $p=0.859$ ($p>0.05$). The intensity of exercise was also unrelated to an athlete's performance, as indicated by the value for p of 0.259% ($p>0.05$). Intensity is not related to sports achievement, but rather to the training/match schedule and frequency. The variable training years had a $p=0.524$ ($p>0.05$) value. In this connection, the years of training is calculated from the time athlete first debuted on the sports to the age at which data was collected. The study's interesting findings revealed that athletes who had been training for less than ten years had a higher proportion of competing at the international level, namely 29.8%. Senior athletes who have been training for a long time (> 10 years) have a lower proportion of competing at the international level (21.4%) than those who have only been training for a short time (5-10 years). Furthermore, exercise frequency was the only variable that significantly correlated with an athlete's sporting performance, with a $p=0.014$ ($p<0.05$). International athletes are known to train more frequently than their national counterparts (28.6%). Athletes who train less than five days per week are more likely to be national-level competitors (34.5%). With an OR (Odds Ratio) of 1.116, the analysis results show that athletes who practise occasionally are more likely to become national athletes.

Discussion

The implementation of a long-term athlete development program has been initiated in Indonesia, with a current emphasis on youth athletes as the central focus of sports coaching and development within the nation. Due to the lack of precise data on the age at which elite athletes in Indonesia focus on specific sports. Therefore, the objective of this study is to examine the correlation between the age at which athletes focus on specific sports and various factors associated with training components, including exercise intensity, duration, and frequency, in relation to sport achievements among elite athletes across different sports in Bandung. The study primarily involved adolescents aged between 12 and 25 years old. The bivariate analysis revealed that there was no correlation between age and athlete performance. Only one-third of international pre-junior athletes returned as senior athletes, according to a study; therefore, it is not guaranteed that the earlier an athlete begins competing, the better he will perform (Barreiros et al., 2014). Other studies of Olympic athletes have shown that early career debut and specialized training programs for teenage athletes do not correlate with senior athlete success in international elite sports (Vaeyens et al., 2009).

Exposure of young athletes to intensive exercise is known to increase the chance of injury and burnout (Myer et al., 2015). One of the potential injuries due to early sports specialization is overuse injuries, which specifically target young athletes (Mosher et al., 2022). The growth plates, vulnerable areas near long bones that are still developing, are susceptible to overuse injuries in children. This is because new bones, referring to the growth plates, are forming, making them more prone to sports injuries. In early sports specialization with a focus on one sport, the growth plate doesn't get sufficient time to recover between the strains of physical activities (Wik et al., 2020). Moreover, acute injuries not only lead to temporary inconvenience; for example, a sprained ankle may prevent a person from taking part in sport for a few weeks (Romero-Morales et al., 2024). The risk of overuse injury is higher when a child's bones are still developing, reinforcing the connection between risk factors of acute injuries. The increased popularity of competitive youth sports and the pressure to play at elite levels have led to an increase in overuse and traumatic injuries in children (Caine et al., 2022). This condition can last for two to three years because the growth plates and associated pain will only resolve once the growth plates have closed, typically around age 15 for girls and 17 for boys (Rajendiran et al., 2018; Sadykov et al., 2016). The intensity of training in one sport category should be postponed until late adolescence to maximize future success and minimize the risk of injury, psychological stress, and burnout (N. Jayanthi et al., 2013).

The results from the analysis conducted in this study indicate that there is no correlation between gender differences and sports achievement. It is often believed in sports that men are considered physically and psychologically superior to women (Hogue, 2020). Male and female athletes typically show a performance gap of 10% to 30%, which is influenced by the specific demands of each sport. The most significant performance gap between men and women is seen in sports that heavily depend on muscular strength, like weightlifting and jumping event (Hunter et al., 2023). Male athletes usually perform better than female athletes in physical abilities, with variations in factors like body fat, muscle mass, maximum oxygen consumption (VO2 max), and aerobic endurance (Puccinelli et al., 2022). Anthropometric characteristics, such as body measurements, play a role in these differences, with male athletes often having more strength and agility in their lower and upper bodies (Carter-Thuillier et al., 2019). Participating in elite sports activities appears to reduce the differences in body composition between male and female athletes(Mascherini, 2017). A study found that male athletes exhibited higher levels of mental toughness than female athletes (Kilic & Yildirim, 2020). According to (Nezhad & Besharat, 2010), both male and female athletes have the same resiliency and toughness in coping with mental problems, as well as the same drive to achieve success in sports. Similarly, (Abrahamsen et al., 2008), discovered that male and female elite athletes share the same motivation and commitment to reach the highest levels of success in their sports careers.

The findings from this study indicate that, of all the tested variables, only exercise frequency has a significant effect on sport achievement. Athletes who train more frequently than five times per week are more likely to achieve international success. Based on scientific research, talented athletes require 8 to 12 years of training to reach the level of an elite athlete. This rule is known as the 10-year rule or the 10, 000-hour rule, which states that before an athlete can be considered an elite/professional, he or she must train three hours per day for ten years (Ericsson & Harwell, 2019; Salmela-Aro, 2009). A study related with the frequency of exercise in soccer players indicated that five days/week of exercise can

improve upper and lower-body strength, endurance in running, and better body composition (Hoffman et al., 1990). Another study reported that resistance training in adolescent effect's muscle quality if it is done at least two times/week (Naimo & Gu, 2022). High-frequency exercise with a high intensity has both pros and cons; young athletes who engage in intensive training run a greater risk of injury but have a greater chance of being recruited and receiving scholarships (Ahlquist et al., 2020). Research shows that 50% of male and female athletes who spend 4.5 days/week on moderate-high intensity training report suffering from chronic injuries (Vetter & Symonds, 2010). In this context, Bandung's athletes have a high chance of becoming international elite athletes in the future. This must be considered with age-appropriate development. Early exposure to high-intensity exercise by athletes can have detrimental physiological and psychological consequences later in life. In addition, the best model of talent development has intentional practice activities and it's deliberate practice designed to enhance the performance of athletes because it's organized to improve specific aspects of performance and athletes are told to attend to their performance. The findings suggest multidisciplinary practice experiences are associated with gradual initial discipline-specific progress but greater sustainability of long-term development of excellence (Güllich et al., 2022). So it's going to be more important during this period of time to incorporate varied motor activities. And that's the problem of early sport specialization.

CONCLUSION

This study revealed that the variables of age, stage of specialization, gender, duration and intensity of exercise have no correlation with sport performance. The exercise frequency has a significant effect on sport achievement. Athletes who train more than five times per week perform better than those who train fewer than five times per week. A major limitation of this study is that it is correlational, and causal conclusions cannot be drawn from the findings. The study only examined changes in sport specialization as a group variable and did not account for individual changes in sport specialization status over time. Furthermore, we did not account for the specific sport or type of sport when examining the relationship between injury and sport specialization. It is recommended to evaluate this in studies focused on specific sports. Bias in talent identification must be anticipated, particularly in later samples, because a larger sample size of young athletes across elite, professional, and amateur levels is required. Another limitation is that the study only examined developmental participation based on broad categories of sport activities without considering variations within each type of activity, such as different types of individual exercises or ways athletes perform exercises in coach-led practice sessions. Finally, this study did not explore potential interactions of other factors with participation patterns, including athletes' psychological traits, family socialization and support, genotype, or gene-environment interactions.

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