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The Relative Age Effect and Injury Burdens among Malaysian Collegiate Track and Field Athletes

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Abstract: This study investigated the Relative Age Effect (RAE) with training exposure and injury prevalence in Malaysian collegiate track and field athletes. Specifically, the aim of the study was to determine if there are differences in training volume and reported injury prevalence across birth quartiles and to investigate the association between training volume and injury outcomes. A cross-sectional quantitative approach was used which comprised 54 Malaysian collegiate track and field athletes (29 males, 25 females; M = 22.11 ± 2.09 years) recruited through criteria-based sampling. Demographic information, retrospective training exposure and injury history were provided using an adapted Participation History Questionnaire. Injury burden was defined as mean annual number of injury weeks, and injury rate was defined as injury rate per 1000 training hours. Birth dates were divided into 4 quartiles (Q1-Q4). The Spearman correlations between average annual training hours and injury outcomes for male and female athletes were small and not statistically significant. Furthermore, statistically significant differences were not found between birth quartiles in average training hours (H = 1.11, p = .774), average weeks of injury (H = 4.01, p = .260) and injury rate per 1,000 training hours (H = 4.11, p = .250) with effect sizes ranging from negligible to small. These results indicated that birth quartile is not a significant determinant of training exposure or injury prevalence at the collegiate level. Although RAE may affect the early selection pathway, the impact of RAE appears to diminish by collegiate participation (i.e., more attenuation on injury risk). Injury prevention strategies in collegiate track and field should therefore focus on individual workload monitoring and adaptive capacity rather than the relative age-based category.

Keywords: Track and Field, Birth Quartile, Relative Age Effects, Injury Prevalence

1. Introduction

Relative Age Effect (RAE) is defined as a systematic advantage given to individuals who are born earlier in a selection year, and are consequently overrepresented in organized sport systems that are based on the age-grouping structure [1-4]. Extensive evidence shows that relatively older athletes benefit from maturational advantages of physical capability, cognitive development and psychosocial confidence, which together means that they are more likely to be selected early and remain in the sport [5-7]. While RAE has been widely investigated in the context of athlete selection and performance outcomes, the implications of RAE on athlete health, especially injury prevalence, have still been comparably underexplored, especially outside the context of youth sport [8-11]. Injury is a crucial determinant of athlete development and retention, and the interaction between injury and selection biases within the system (RAE) needs to be more closely examined. In track and field, given the high training demands and wide-ranging, specific demands of each event, even modest differences in development can significantly translate to meaningful differences in cumulative exposure to physical stressors [12-13]. Within this context, birth quartile could act as an indirect but influential factor on injury risk via pathways associated with selection, training opportunity, and accumulated workload instead of chronological age alone [8-9]. Although there have been global studies that had started to examine this association, the applicability of these findings to Malaysian collegiate track and field athletes who function in different developmental, cultural and institutional systems remains unclear. Therefore, knowing if injury prevalence varies across birth quartiles at the collegiate level is therefore imperative to assess the longer-term health implications of relative age-based advantages that may have originated earlier on in the developmental pathway of an athlete.

As an illustration of this theory-based perspective, the association between birth quartile and the prevalence of injuries can be understood in terms of interactive developmental mechanisms called Relative Age Effect (RAE) frameworks, especially as outlined by previous studies [5], and can be understood within the conceptual framework of the adapted model in Figure 1. The Matthew Effect implies that relatively older athletes experience cumulative advantages over time, such as increased selection, training volume and competitive exposure, thus, this may increase the long-term risk of injury due to increased cumulative physical loads as revealed in previous research [14-15]. Concurrently, the Pygmalion Effect emphasizes the influence that coach expectations may have given to perceived maturity and early performance by more responsibility and intensifier training demands in early-born athletes [16-17]. These external expectations may inadvertently make athletes more injury susceptible by increasing exposure before there is adequate physiological adaptation [18]. Complementing this, the Galatea Effect emphasizes on internalized self-belief, whereby relatively older athletes develop increased confidence and self-efficacy, reinforcing continued participation despite injury symptoms or fatigue [19]. Collectively these mechanisms provide a reason to think that the advantages of RAE may not be uniformly protective, but instead introduce hidden health costs over time. This perspective is in line with emerging research in injury epidemiology which states that injury risk is not only determined by absolute training load but also by the pattern of prolonged exposure and early specialization [20-21]. In the context of track & field, the early-born athletes are subject to being channeled into high-demand events & competitive paths earlier on and may accumulate higher levels of musculoskeletal stress over their lifetime as athletes [13, 22]. Importantly, these mechanisms are not postulated to be deterministic, but rather as interacting developmental processes through which relative age-based advantages may influence long-term exposure profiles and injury susceptibility.

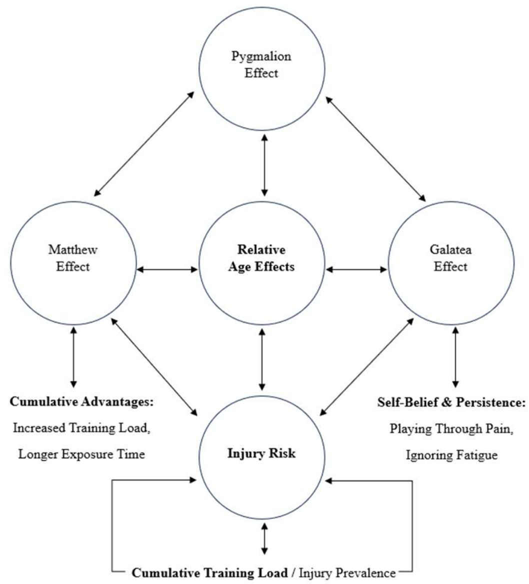

Figure 1. A Conceptual framework to illustrate how relative age effects (RAE) may influence injury risk through interacting developmental mechanisms. Framework adapted from Hancock et al. [5].

Consequently, there is empirical evidence to support the plausibility of a birth quartile-injury relationship, but results differ at different ages and competitive levels. Previous studies showed an effect of age on injury risk in youth sport, showing an increased risk of injury in relatively younger athletes in early childhood but an inverted relationship in adolescents, with relatively older athletes having a greater prevalence of injury [9]. This reversal was attributed to greater exposure to training and greater competitive demands imposed on the early selected athletes over time. Similar trends have been found in other high-performance youth environments in which relatively old athletes tend to suffer more injuries because they have more playing time and are exposed for a longer duration than because of poor physical readiness [8]. In track and field in particular, cumulated loading, event specialization, and training history all seem to be interrelated with injury risk, which may be indirectly determined by indirect selection processes based on relative age [12,23]. However, most of the existing studies have been conducted on youth or elite senior populations in the Western world, which is a limitation of their research in terms of generalizability [8-9]. Within Malaysia, there has been consistent research to identify RAE in youth and school level athletics, with early born athletes over-represented in selection to higher competitions [24]. Whether these initial structural advantages continue into collegiate sport and whether they transfer into differential prevalence of injury between birth quartiles has not been empirically determined. Given that the collegiate sport represents an important transition phase with increased training and increased risk of injury, this gap is of particular consequence.

Despite the increasing awareness of RAE in Malaysian sport, the current literature has mostly focused on selection patterns and performance outcomes and there has been minimal focus on the consequences to athlete health [24-26]. Specifically, there have been no known studies in Malaysia that systematically assessed whether there is a difference in the prevalence of reported injuries between birth quartiles in collegiate track and field athletes. This is not without note, since collegiate athletes are often the culmination of long-term developmental processes influenced by earlier selection biases, training exposure and institutional expectations [27-28]. If relatively older athletes do have higher levels of injury prevalence, because of accumulated workload over time and prolonged exposure, then this would challenge the assumption that selected advantages are uniformly beneficial at an early age. Addressing this uncertainty is critical to informing strategies for developing and preventing injuries in athletes equitably in Malaysian athletics. Therefore, the present study aims to examine the existence of differences in reported injury prevalence across birth quartiles among Malaysian collegiate track and field athletes to add novel evidence on the health-related implications of Relative Age Effect in this under-researched population.

1. Materials and Methods

Research Design

This study utilized a cross-sectional quantitative research design to investigate the differences in the prevalence of reported injury across birth quartiles in Malaysian collegiate track and field athletes. A cross-sectional approach was suitable given the purpose of the study, to identify between-group differences at one point in time, rather than causality [27]. The design provided an opportunity to compare efficiently the prevalence of injuries among predefined birth quartiles as in previous studies conducted [28].

Participants

The sample size for the current study was chosen according to the recommendations of G*Power analysis (Version 3.1.9.7) in order to detect meaningful effects [21]. However, there was limited available information for a priori power calculation specific to comparisons between birth quartiles (Kruskal-Wallis distributions) to guide sample size because of limited prior evidence guiding expected birth quartile related differences in injury outcomes among Malaysian collegiate track and field athletes. As a pragmatic approximation, power was assessed by a one-way framework of an Analysis of Variance (with 4 groups) (a=.05). Under this model, the attained sample size (N = 54) has about 80% power to only detect very large between-quartile effects (Cohen's f = 0.47). Accordingly, the study may be underpowered to detect small to moderate differences and effect sizes were therefore reported to help with interpretation. Based on the study's research question, the participants were 54 Malaysian collegiate track and field athletes (M=22.11 years; SD=2.09 years) recruited using the criterion-based sampling method. The inclusion criteria included the male and female athletes to be actively participating at the collegiate level with a minimum history of structured track and field participation in any event.

Procedures

Data collection was performed with an adapted Participation History Questionnaire (PHQ) by Ford et al., a retrospective self-report instrument that is commonly used to obtain information about long-term sport participation and injury history [30]. Data collection in person with the athletes at their training grounds under standardized conditions was carried out by the lead researcher. Participants were asked to recall time-loss injury with possible accuracy in their entire track and field participation history and to use important competition seasons and training phases as reference points. Participants provided information on the total number of weeks per year in which they could not participate in track and field because of injury during the course of their athletic career. An injury was defined as any physical complaint as a result of track and field participation that resulted in complete inability to train or compete for at least one week [31]. Therefore, for the purpose of analysis, injury burden was operationalized as average annual injury weeks, which was calculated by dividing the total number of self-reported injury related time-loss weeks by the total number of years of track and field participation [12]. This is a standardized measure that allowed for meaningful comparison among athletes with different lengths of athletic involvement. Birth dates were collected and verified independently of quartile assignment. Athletes were assigned to 4 birth quartiles according to their month of birth: Quartile 1 (January-March), Quartile 2 (April-June), Quartile 3 (July-September) and Quartile 4 (October-December). The use of birth quartiles allows for the operationalization of relative age within an annual selection system, reflecting systematic differences in biological maturation, early selection opportunities, and cumulative training exposure [1-7]. This provides a structured method to examine whether developmental advantages associated with RAE extend beyond performance into health-related outcomes. All procedures were performed in accordance with the Declaration of Helsinki and were approved by the ethic committee (Reference Number: 2025-0816-01). Written informed consent was collected from all participants before data collection.

Statistical Analysis

All statistical analysis were conducted using the computerized software package, statistical package for social science (SPSS, Version 26). Descriptive statistics were initially calculated to describe the prevalence of injuries between the four birth quartiles. Normality of the data for injuries was evaluated with the Kolmogorov-Smirnov test which showed non-normality. Due to this, a Kruskal-Wallis H test was performed to test for differences in reported prevalence of injury across birth quartiles. This non-parametric approach was appropriate because the injury data were non-normally distributed and highly skewed. Statistical significance level was set at $p < .05$.

2. Results

3.1. Descriptive Statistics

Table 1. Demographic Characteristics of Participants by Gender.

Variable	Category	Male (*n* = 29)	Female (*n* = 25)
Age (years)	Mean ± SD	21.41 ± 1.96	21.96 ± 2.42
Birth Quartile	Q1 (Jan–Mar)	11 (37.9%)	6 (24.0%)
	Q2 (Apr–Jun)	4 (13.8%)	9 (36.0%)
	Q3 (Jul–Sep)	8 (27.6%)	5 (20.0%)
	Q4 (Oct–Dec)	6 (20.7%)	5 (20.0%)

Table 1, displays a total of 54 Malaysian collegiate track and field athletes were included in the study consisting of 29 males and 25 females. The mean age of male athletes was (M=21.41; SD=1.96 years), the mean age of the female athletes was (M=21.96; SD=2.42 years). Birth quartile distribution reflected the higher representation of athletes born in the first quartile (January-March), especially for males, although the different birth quartiles were represented by athletes of both genders. Among the male athletes (n=29) those born in the first Quartile (January-March) were the highest number of athletes (37.9%) followed by Quartile 3 (July-September) (27.6%), Quartile 4 (October-December) (20.7%), and Quartile 2 (April-June) (13.8%). Among female athletes (n=25), the highest proportion was found for Quartile 2 (April-June) (36.0%). Athletes who were born in Quartile 1 (January-March) represented 24.0%; while 20.0% represented in Quartiles 3 and 4 for the total sample of females.

Table 2. Descriptive statistics of training exposure and injury outcomes by gender.

Variable	Gender	*n*	Mean ± SD
Total Training Hours	Male	29	5263.85 ± 3524.64
	Female	25	7430.29 ± 5514.87
Total Injury Weeks	Male	29	7.50 ± 16.98
	Female	25	15.36 ± 30.18
Years of Participation	Male	29	8.61 ± 3.32
	Female	25	10.60 ± 4.50
Average Training Hours (per year)	Male	29	674.15 ± 526.52
	Female	25	798.45 ± 630.13
Average Injury Weeks (per year)	Male	29	1.17 ± 2.80
	Female	25	1.90 ± 3.85
Injury Rate (per 1,000 hours)	Male	29	2.86 ± 8.12
	Female	25	5.28 ± 14.79

The descriptive statistics for training exposure and injury related outcomes stratified by gender are presented in Table 2. Male athletes (*n*=29) accumulated a mean total training volume of (*M*=5263.85; *SD*=3524.64 hours), while female athletes (*n*=25) reported a higher mean total training volume of (*M*=7430.29; *SD*=5514.87 hours). The average number of years of participation was (*M*=8.61; *SD*=3.32 years) for males and (*M*=10.60; *SD*=4.50 years) for females. When expressed on an annual basis, male athletes reported an average of (*M*=674.15; *SD*=526.52 training hours per year), whereas female athletes reported (*M*=798.45; *SD*=630.13 hours per year). With respect to injury outcomes, male athletes reported (*M*=7.50; *SD*=16.98 total injury weeks), compared with (*M*=15.36; *SD*=30.18 total injury weeks) among female athletes. Injury burden, calculated as injury weeks per year, was highly positively skewed in both groups, with a median of 0.00 weeks per year, indicating that most athletes reported no time-loss injury. Male athletes reported (*M*=1.17; *SD*=2.80 injury weeks per year) (*n*=29), while female athletes reported (*M*=1.90; *SD*=3.85 injury weeks per year) (*n*=25). Injury rates expressed per 1,000 training hours were (*M*=2.86; *SD*=8.12) for males (*n*=29) and (*M*=5.28; *SD*=14.79) for females (*n*=25). Across all injury related variables, substantial within-group variability was observed.

3.2 The Relationship Between Training Volume and Prevalence of Injury

Table 3. Spearman's correlation significance values

Variable Pair	Gender	ρ	*n*	*p*
Average Training Hours & Injury Weeks per Year	Male	−.268	29	.160
	Female	−.083	25	.701
Average Training Hours & Injury Rate per 1,000 Hours	Male	−.285	29	.142
	Female	−.161	25	.443

The correlation analysis were conducted to examine the relationship between training volume and injury outcomes, with analysis stratified by gender. As shown in Table 3, average training hours demonstrated weak negative associations with both injury measures in male and female athletes. Among male athletes (*n*=29), average training hours were weakly and negatively correlated with average injury weeks per year (ρ=−.268, p=.160). A similar weak negative association was also observed between average training hours and injury rate per 1,000 hours (ρ =−.285, p =.142). Neither association reached statistical significance. Among female athletes (n=25), average training hours also showed weak negative correlations with average injury weeks (ρ=−.083, p=.701) and injury rate per 1,000 hours (ρ=−.161, p=.443). These relationships were likewise not statistically significant. Overall, the results indicate that training volume was not significantly associated with injury prevalence, regardless of whether injury was expressed as average injury weeks or injury rate per 1,000 training hours, in both male and female athletes.

3.3 The Comparison of Training and Injury Profile Across the Birth Quartile

Table 4. Kruskal-Wallis Test Comparing Training and Injury Variables by Birth Quartile

Variable	Birth Quartile	*n*	Mean	SD	Mean Rank	Kruskal-Wallis H	*df*	*p*
Average Training Hours	Q1	17	683.28	613.80	25.24	1.11	3	.774
	Q2	13	667.73	449.61	26.77			
	Q3	13	664.32	414.47	27.77			
	Q4	11	900.44	823.01	31.55			
Average Injury Weeks	Q1	17	0.45	0.91	22.41	4.01	3	.260
	Q2	13	1.30	2.93	26.46			
	Q3	13	3.49	5.47	32.73			
	Q4	11	0.96	1.41	28.05			
Injury Rate / 1000 Hours	Q1	17	1.02	2.10	23.12	4.11	3	.250
	Q2	13	1.60	2.94	26.88			
	Q3	13	12.21	21.77	33.35			
	Q4	11	1.38	2.96	25.50			

The differences in training exposure and injury outcomes across birth quartiles were examined using the Kruskal–Wallis H test, with effect sizes estimated using eta-squared for Kruskal–Wallis (η^2_h). Descriptive statistics, test statistics, and effect sizes are presented in Table 4. For average training hours, no statistically significant differences were observed across birth quartiles (H = 1.11, df = 3, p = .774). The corresponding effect size was negligible ($\eta^2_h \approx 0.00$), indicating minimal between-quartile differences in training exposure. Similarly, average injury weeks per year did not differ significantly across birth quartiles (H = 4.01, df = 3, p = .260). The associated effect size was small (η^2_h = 0.01), suggesting limited variation in injury prevalence across quartile groups. Analysis of injury rate per 1,000 training hours also revealed no statistically significant differences across birth quartiles (H = 4.11, df = 3, p = .250). The effect size for this comparison was small (η^2_h = 0.02), indicating a low magnitude of quartile-related differences in injury rate. Overall, the Kruskal–Wallis analysis demonstrated that birth quartile was not associated with meaningful differences in training volume or injury prevalence, with effect sizes ranging from negligible to small across all outcome variables.

3. Discussion

The present study investigated Relative Age Effect (RAE) as related to injury prevalence in Malaysian collegiate track and field athletes in terms of the relationship between training volume and injury prevalence and differences in training exposure and injury outcomes using birth quartiles. Overall, the results showed that there was not a significant relationship between training volume and injury prevalence and that birth quartile did not significantly affect either training exposure or injury outcomes.

The correlation analysis showed weak negative correlations that were not statistically significant between the average annual training hours and the injury weeks per year alongside with the injury rate per 1,000 training hours in both male and female athletes. These findings are consistent with modern models of workload and injury, which call for a stress and strain model of injury where injury risk does not always depend on the absolute amount of training completed, but is instead influenced by cumulative adaptation, load progression and exposure consistency [11-12]. Furthermore, it is also possible that training volume cannot accurately predict injury risk because of methodological limitations and the multifactorial nature of the injury, including biomechanical factors, stress and recovery [32-34]. Injury risk also varies depending on gender, body composition, and type of sport, for example, higher muscle to fat and BMI contributes to upper limb injury risk in female athletes, while other effects of age vary depending on the sport and gender [35].

Consequently, the results showed that the female athletes accumulated more total training hours and reported higher injury related values in a descriptive manner; however, large standard deviations and highly positively skewed injury distributions indicate that injury burden was concentrated among a small subset of athletes rather than evenly distributed across the sample [36]. This pattern is consistent with epidemiological evidence of the heterogeneity of injury occurrence in athletics and the high likelihood that individual susceptibility (rather than training volume in isolation) is involved [9-10]. The risk of injury is also affected by the mechanical properties of individual tissues including stiffness and viscoelasticity and the physiological state which may affect the manner in which stress and strain results in acute or overuse injuries [37-38]. Lack of significant positive associations further indicates that athletes that are exposed to increased chronic workloads may acquire greater physiological resilience, neuromuscular coordination and tissue tolerance over time, to mitigate injury risk despite increased exposure [12]. In fact, studies have shown that graded increases in chronic workload with the correct acute: chronic workload ratios assist in the development of physical tolerance, in turn, enhancing resilience to injury [39]. Consequently, these findings oppose simplistic assumptions regarding the positive association between training volume and injury risk and reinforce the importance of taking into consideration training history and adaptation processes when assessing injury outcomes in collegiate populations.

Contrary to theoretical expectations based on RAE frameworks, no statistically significant differences were found between training exposures, injury weeks per year, or injury rates by birth quartile. Although the descriptive mean values of injury characteristics were higher in athletes born in Quartile 3, the differences were small and associated with negligible to small effect sizes (low practical significance). These findings suggest that RAE-related disparities may attenuate by the collegiate stage where biological maturation is essentially complete and athletes have accumulated a great deal of training experience, in line with previous empirical evidence [2,8,10]. This is plausible since by the time athletes are at the collegiate level of participation the earlier RAE related disadvantages are likely to be filtered through long-term selection processes [28]. Athletes who persist to the collegiate level represent a selectively retained subgroup who have successfully adapted to cumulative training demands and competitive pressures over time. As a result, relatively younger athletes who continue to this stage could be a more resilient or higher quality subset as they have been able to adapt to increasing competitive demands across development [28,40]. This may reflect a survivorship effect which dilutes between-quartile differences in both exposure and injury outcomes, that may mask patterns evident during earlier developmental stages.

The results of the current study have a number of implications important to athlete development systems and injury prevention practice. The lack of significant relationships between training volume and injury occurrence supports the idea that absolute training volume is not a sufficient measure of injury risk in collegiate track and field athletes. This is consistent with more recent views that focus on the importance of quality of load management, such as progression, recovery and chronic exposure tolerance, rather than absolute training volume [11-12]. Furthermore, the results indicate that injury prevention programs should focus on individual monitoring rather than structural categorization, such as birth quartile or relative age [36]. Previous studies have revealed that individual physiological characteristics and susceptibility may play a larger role in injury burden than training volume alone [41]. While RAE is still a vital consideration of promoting equity in youth sport systems, its usefulness as a risk stratification tool to prevent injuries in more mature athletic populations appears to be limited. Consequently, sport scientists and coaches should be concerned with monitoring training load dynamics, recovery behaviors, and athlete-specific responses and not assume vulnerability based on relative age status.

Despite the contributions of the current study, there are several limitations that have to be recognized. First, the cross-sectional design limits the ability to infer causal relationships between the birth-quartile, training exposure and injury prevalence. Furthermore, the data for the injuries were obtained with a retrospective self-report questionnaire, which introduces the potential for recall bias and misclassification [42]. Athletes may underreport injuries especially those that are considered minor or those that have not resulted in prolonged time-loss. Third, the sample size was sufficient to detect only large effects and may have been underpowered to detect small to moderate differences, especially when data were stratified by gender and birth quartile. The small cell size in some of the quartiles raises the thresholds for Type 2 error, which means that non-significant results should not be taken as strong evidence for the absence of an effect [43]. This is particularly relevant to injury outcome, which is known to have high inter-individual variability across sport populations [44]. Future research should adopt longitudinal designs that track athletes across developmental stages on their training exposure and injury over time, by integrating objective load-monitoring metrics such as GPS-derived external load, or acute: chronic workload ratios to improve precision in estimating injury risk.

4. Conclusions

The training volume was not significantly associated with injury prevalence and there were no meaningful differences in training exposure and injury outcomes by birth quartiles. Although there was evidence of descriptive variability, effect size estimates were small and therefore of limited practical significance. These results suggest that although relative age-based advantage may affect early selection and participation pathways, the impact on injury risk seems to fade at the collegiate level where athletes have largely converged in terms of biological maturity and accumulated training experience. Consequently, birth quartile does not seem to be a useful marker of injury susceptibility in this population. Overall, the current study offers new evidence from a Malaysian collegiate setting in which individualized monitoring of loads, adaptive capacity and training quality are highlighted as important in injury prevention and management of athletes, rather than being determined by structural factors, such as relative age.

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