

Heading in youth soccer: Quantifying exposure and head injury risk in male and female U16 players

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Abstract

Background: Heading is a fundamental technical skill unique to football, allowing players to deliberately use their unprotected heads to control, pass, or score. However, concerns have emerged regarding the safety of this skill, particularly for young athletes who may be more vulnerable to high-acceleration forces. This study aimed to examine the frequency, types, and characteristics of headers among youth football players under 16, assess the mechanical load associated with their execution, and investigate the occurrence of head injuries. **Materials and Methods:** Eighteen teams (10 male and 8 female) comprising 15- and 16-year-old athletes participated in the study. Each team was video-recorded during one randomly selected training session and one official match. The types and characteristics of headers, as well as any injuries, were documented using standardized observation forms. **Results:** Boys performed significantly more headers than girls during training, while no differences were found during matches. In both sexes, headers were more frequent in matches compared to training. One female team recorded 132 headers in a single training session, a frequency considered potentially concerning. Most headers were intentional, executed with the frontal part of the head, and followed short ball trajectories (<5 m), indicating sound technique and lower head acceleration. Nevertheless, a notable proportion—especially among boys—involved the parietal region of the head, suggesting suboptimal technique. Additionally, several headers occurred after long trajectories (>10 m) or from free kicks, conditions linked with higher impact magnitudes. Importantly, no head injuries were observed during either training or matches, resulting in an incidence rate of zero. **Conclusions:** While the majority of headers were technically appropriate and likely associated with lower forces, instances of poor technique and high-risk conditions were also evident. The absence of documented head injuries is encouraging but should not be interpreted as definitive evidence of safety. Reducing exposure to potentially high-impact headers may help protect young footballers in the long term.

Key Words: football, adolescents, heading, injuries, concussion

Introduction

Football is one of the most widely played sports globally, with participation steadily increasing—particularly among children and adolescents (López-Valenciano et al., 2020; Madarsa, & Mohamad, 2022). The sport's popularity is largely sustained and reinforced by the ease of access to participation, ranging from informal playing areas to modern sports facilities. Regardless of age, sex, or skill level, all players are required to perform core technical actions such as dribbling, passing, heading, and shooting. These fundamental skills form the basis of game behavior and are consistent across all levels of play, from amateur to professional (Kafesakis et al., 2025; Kaya, Tutar, Caglayan, & Korkmaz, 2025). Special attention has been given to heading, as it represents a unique phenomenon in sport: football is the only sport in which players purposefully use the head to make contact with the ball. This distinct feature makes heading a subject of particular interest from both a technical and biomedical perspective (Beaudouin et al., 2020).

Heading, as a technique involving the deliberate use of the unprotected head to control or propel the ball, carries the risk of head injury. Recent concerns in football regarding head injury management stem from the potential link between repeated head impacts—such as concussions and sub-concussive blows—and the development of chronic traumatic encephalopathy, a neurodegenerative condition with psychiatric symptoms (Harriss, Johnson, Walton, & Dickey, 2018). The term *sub-concussive* refers to head impacts that may cause neuronal changes without clinical concussion symptoms (Beaudouin et al., 2020). Interest in youth football has intensified, particularly following studies suggesting that repetitive heading may negatively affect brain function, especially in children under the age of 12, whose developing brains may be more vulnerable (Harriss et al., 2018). However, it remains unclear whether intentional heading constitutes repetitive minor trauma, and no definitive cause-and-effect relationship with long-term brain damage has been established (Beaudouin et al.,

2020). Additionally, although laboratory testing provides valuable insights, it does not accurately replicate the real-world context of heading in soccer. In laboratory or research settings, players often perform multiple consecutive headers within short time intervals (Kaminski, Cousino, & Glutting, 2008)—conditions that do not typically occur during actual match play or training. Nonetheless, since definitive evidence is inconclusive due to conflicting results across different studies (Comstock et al., 2015; Harper, Aron, & Soandra, 2023; Peek et al., 2023), repeated exposure of the brain to mechanical forces is still considered a potential risk factor of neurodegenerative disease (Scottish Football Association, 2021).

Over the past decade, scientific investigation into the short- and long-term consequences of systematic football participation—particularly heading—has intensified significantly, both at the level of professional athletes and among youth players (Beaudouin et al., 2020; Sandmo, Andersen, Koerte, & Bahr, 2020). Notably, longitudinal epidemiological data from U.S. high schools identified heading as the match activity most frequently associated with concussion. However, a closer examination reveals that the primary injury mechanism is not the act of heading itself, but rather player-to-player contact occurring during heading attempts. In fact, while heading is commonly implicated in soccer-related concussions, the majority of these injuries result from contacts between players (Comstock et al., 2015). Apart from the frequency of headers, a critical factor related to their risk is the manner in which they are executed, the distance the ball has traveled prior to contact with the head, and the velocity of the ball at impact. These parameters influence the force transmitted to the head during each header (Harriss et al., 2018; Wahlquist & Kaminski, 2021). Proper heading technique—using the forehead rather than the top of the head and activating neck musculature—(Beaudouin et al., 2020; Harriss et al., 2018) can mitigate head acceleration, while poor technique may result in higher head impact forces. Additionally, ball velocity and game context (e.g., goal kick versus throw-in) contribute to variability in impact forces. Thus, identifying differences in heading technique across age groups and match scenarios is essential to guide safe training practices. Such insights could guide coaching practices to promote the development of safer, more effective heading techniques (Harriss et al., 2018; Peek, Vella, Meyer, Beaudouin, & McKay, 2021). To support this, further research is urgently needed. Key priorities include accurately documenting the frequency of headers, determining the specific points of ball impact on the skull, and recording the incidence and types of heading-related injuries. These factors should be examined in relation to age, level of participation, and sex to provide comprehensive insights that can inform evidence-based guidelines for youth football training and safety.

Considering that existing laboratory studies often fail to replicate real game conditions, leaving a critical gap in evidence-based knowledge, a practical solution can be found in the conduction of observational studies in naturalistic contexts. By systematically video-recording both training sessions and official matches, the frequency, types, and technical execution of headers can be accurately captured under realistic playing conditions. Such knowledge is crucial for understanding the real demands placed on players, evaluating potential short- and long-term health risks, and informing the development of evidence-based strategies for player safety and performance optimization.

The aim of the present study was to examine, through systematic video recordings, the frequency, types, and characteristics of headers among youth football players under the age of 16 (U16), during both training sessions and official match play, to estimate the mechanical load associated with their execution and to investigate the occurrence of head injuries.

The significance of this research lies in its potential to provide valid insights into the nature and demands of heading in players under 16 years old. Ultimately, this knowledge can inform evidence-based guidelines for training practices, injury prevention strategies, and policy decisions aimed at safeguarding the health and long-term well-being of young athletes.

Materials & Methods

Inclusion criteria

To be eligible for inclusion in the study, teams should involve male or female players from 15 to 16 years old (Under-16 [U-16]). Clubs were also required to be officially registered with the local Football Clubs Associations, operating under the governance of the Hellenic Football Federation, thereby ensuring participation in officially sanctioned matches. Additionally, all teams had to be based in the region of Thrace (Greece) and engage in regular training sessions. Mixed teams were excluded (i.e. those engaging both male and female players).

Participants

A total of 18 teams (10 male and 8 female) participated in the study. The male teams engaged 190 players in the trainings and 110 players in the matches, while the female teams involved 110 athletes in training and 88 in matches. The players and their legal guardians provided informed consent.

Study design

The study was observational and was based on video-recordings. All teams were video-recorded during one randomly selected training session and one official match per team. For the video recordings, an iPhone 8 Plus mobile device was used, set to high-definition resolution. All recordings were conducted from a position outside the playing field. Following the observation and analyses of each recorded session (training session or

match), two standardized observation forms were completed: the “Header Recording Form” and the “Head Injury Reporting Form.”

Measurements

Heading recording form

The heading recording form was used to document heading actions and included information proposed by Beaudouin et al. (2020) which was the following: a) the type of header (single intentional header; unintentional header; header duel; header during a tackling movement), b) the match situation (free game; header after corner; throw-in header, i.e. the ball is thrown in from the sideline [Harris et al., 2019]; free kick header), c) ball flight distance before head contact (< 5 m, 5–10 m, 10–20 m, > 20 m), d) the player’s position on the field (goalkeeper, defender, midfielder, striker), e) the point of contact of the ball on the head (front, top, back, side, face). Additional information included was the duration of the training or match.

Head Injury Reporting Form

In case a head injury occurred during a match or training session, the head injury form should be completed which contained questions in relation to: the date of injury, diagnosis, the date of full participation in training/matches, the action that led to the head injury (e.g., foul, aerial duel, etc.) and the exact mechanism of injury (e.g., head-to-head contact, elbow to the head, etc.).

Analysis of the data

Analysis of the data was realized with SPSS. The methods used were descriptive statistics and analysis of frequencies. The total training /match exposure in hours was calculated using the following equation: number of trainings/matches x players participating x training duration in hours. The incidence rate (IR) of headers per training or match was calculated through the equation: $IR = (\text{number of headers} / \text{hours of training or match exposure}) \times 1000$. Independent samples t-tests were conducted to compare the IR of headers between male and female teams in training and matches. Significance was set at $p < .05$.

Results

Incidence rates of headers

The total training exposure in hours was 207.80 for male teams and 115.84 for female teams. The total match exposure in hours was 120.80 for male teams and 111.20 for female teams. In total, male teams executed 104 headers during training (Min = 3; Max = 27) and 235 headers during matches (Min = 6, Max = 36). Female teams executed 149 headers during training (Min = 0, Max = 132) and 171 headers during matches (Min = 14, Max = 33). However, in the female teams 132 of the headers during training were performed by a single team. Therefore, for trainings, the overall IR of headers per 1000 h was 500.48 for males versus 1286.25 for females, while for matches the IR was 2036.42 for males versus 1537.77 for females. When excluding the outlier female team from analysis, the IR of headers during training fell to 170.27. The total number of headers per team is presented as means (M) $\pm$ standard deviations (SD) in Table 1. The number of headers per player in Table 1 was calculated by dividing the absolute number of headers by the number of players.

Table 1. Number of headers per team and per player during training sessions and matches (M $\pm$ SD)

	Trainings		Matches	
	Boys	Girls	Boys	Girls
Number of headers per team	10.40 $\pm$ 7.52	18.13 $\pm$ 45.25	23.50 $\pm$ 10.26	21.38 $\pm$ 6.02
Number of headers per player	0.55	1.35	2.14	1.94

Comparing the average IR of headers in training between males and females, no statistically significant difference was found when the outlier female team was included, $t(7.009) = -.652$, $p = .535 > .05$ (equal variances not assumed). However, when excluding this team from analyses, there were statistically significant differences between boys and girls $t(15) = 2.863$, $p = .012 < .05$, with boys executing 538.48 ($\pm$ 255.80) headers per 1000 h, as opposed to 208.95 ($\pm$ 195.56) by girls. In matches, there were no statistically significant differences between boys and girls $t(16) = 1.336$, $p = .100 > .05$, with boys recording 2001.14 ($\pm$ 775.33) headers per 1000 h and girls 1577.18 ($\pm$ 499.9). Overall, both boys and girls exhibited a higher frequency of headers during matches than in training.

Types of headers

During training, for both male and female teams, the most common type of header was the single intentional header, accounting for 82.7% of headers among boys and 97.3% among girls. The second most frequent type for boys was the header duel, representing 13.46%, while no such headers were recorded among girls. Unintentional headers were rare, comprising 3.84% for boys and 2.68 % for girls.

During matches, the single intentional header remained the most common type, comprising 94% of headers for boys and 94.7% for girls. Header duels made up 4.7% of headers among boys and 2.4% among girls. Unintentional headers occurred infrequently, accounting for 1.3% in boys and 2.9% in girls. The types of headers are presented as absolute numbers and as M $\pm$ SD in Table 2.

Table 2. Types of headers for male and female teams (absolute numbers & M ± SD)

	Trainings		Matches	
	Boys	Girls	Boys	Girls
Single intentional header	86 (8.6 ± 5.99)	145 (18.13 ± 45.25)	221 (22.1 ± 9.7)	162 (20.25 ± 5.52)
Header duel	14 (1.40 ± 1.90)	0	11 (1.1 ± 1.1)	4 (0.50 ± 0.76)
Unintentional header	4 (0.40 ± 0.52)	4 (0.50 ± 0.76)	3 (0.3 ± 0.48)	5 (0.63 ± 0.52)

Point of contact with the ball

During trainings, the most common point of contact with the ball was the front of the head (forehead) for both boys (76.9%) and girls (90.6%), followed by the top of the head (boys: 19.2%; girls: 6.7%). Similarly, during matches, the most common point of contact with the ball was the forehead (boys = 80.4%; girls = 88.6%), followed by the top of the head (boys = 17%; girls = 8.4%). All other regions were used minimally by boys and girls in all situations. The points of contact with the ball are presented as absolute numbers and as M ± SD in Table 3.

Table 3. Point of contact with the ball for male and female teams (absolute numbers & M ± SD)

	Trainings		Matches	
	Boys	Girls	Boys	Girls
Front	80 (8.00 ± 6.41)	135 (16.88 ± 43.73)	189 (18.90 ± 9.02)	147 (16.88 ± 5.30)
Top	20 (2.00 ± 1.76)	10 (1.25 ± 1.67)	40 (4.00 ± 3.77)	14 (3.88 ± 2.80)
Back	1 (0.10 ± 0.32)	2 (0.25 ± 0.46)	1 (0.10 ± 0.32)	2 (0.25 ± 0.46)
Side	1 (0.10 ± 0.32)	0	2 (0.20 ± 0.42)	0
Face	2 (0.20 ± 0.42)	2 (0.25 ± 0.71)	3 (0.30 ± 0.48)	2 (0.25 ± 0.46)

Ball flight distance before head contact

In the majority of cases, the ball had travelled only a short distance before making contact with the players' head. During training sessions, the ball covered a distance of less than 5 m in 61.54% of cases for boys and 95.30% for girls. During matches, the corresponding proportions were 52.30% for boys and 67.83% for girls. The second most frequent distance category was between 5 and 10 m, occurring in 30.76% of training instances and 30.64% of match instances for boys, and in 4.02% and 24.56% of cases for girls, respectively. Although ball flight distances greater than 10 m were rare during training, distances between 10 and 20 m were observed more frequently in matches for both boys (13.61%) and girls (7.01%). The distance the ball travelled prior to heading is presented as absolute numbers and as M ± SD in Table 4.

Table 4. Ball flight distance before head contact for male and female teams (absolute numbers & M ± SD)

	Trainings		Matches	
	Boys	Girls	Boys	Girls
< 5 m	64 (6.40 ± 5.32)	142 (17.75 ± 45.39)	123 (12.30 ± 5.62)	116 (14.50 ± 5.83)
5–10 m	32 (3.20 ± 2.78)	6 (0.75 ± 0.70)	72 (7.20 ± 3.33)	42 (5.25 ± 2.82)
710–20 m	8 (0.80 ± 1.23)	1 (0.13 ± 0.35)	32 (3.20 ± 3.49)	12 (1.50 ± 1.31)
> 20 m	0	0	8 (0.80 ± 0.79)	1 (0.13 ± 0.35)

Headers per match situation

Across all conditions, the majority of headers occurred during free play. While the proportion of headers during other match situations was relatively low in training sessions, certain scenarios contributed more substantially during matches. Specifically, headers following throw-ins accounted for 11.49% of total headers in boys' matches and 23.39% in girls' matches. Headers after free kicks represented 17.87% of all headers for boys and 8.19% for girls. Headers following corner kicks constituted 2.61% for boys and 1.75% for girls. The headers per match situation are presented as absolute numbers and as M ± SD in Table 5.

Table 5. Headers per match situation for male and female teams (absolute numbers & M ± SD)

	Trainings		Matches	
	Boys	Girls	Boys	Girls
Free play	95 (9.5 ± 6.5)	141 (17.63 ± 45.03)	157 (15.7 ± 5.49)	114 (14.25 ± 3.84)
Header after corner	5 (0.50 ± 1.08)	3 (0.38 ± 0.52)	9 (0.90 ± 0.74)	3 (0.38 ± 0.74)
Throw-in header	4 (0.40 ± 0.7)	4 (0.50 ± 0.76)	27 (2.70 ± 2.5)	40 (5 ± 3.39)
Free kick header	0	1 (0.13 ± 0.35)	42 (4.2 ± 3.61)	14 (1.75 ± 1.91)

Headers by playing position

Regarding headers by playing position, no headers were recorded by goalkeepers under any condition. During training, defenders performed the highest proportion of headers among boys' teams (42.3%), followed by midfielders (29.8%) and strikers (27.9%). In girls' teams, defenders also accounted for the highest proportion (35.57%), with midfielders and strikers each contributing equally (32.21%).

During match conditions, midfielders executed the largest share of headers in both boys' and girls' teams (43.4% and 46.2%, respectively), followed by defenders (39.2% for boys and 35.7% for girls) and strikers

(17.4% for boys and 18.1% for girls). The headers per playing position are presented as absolute numbers and means ($\pm$ SD) in Table 6.

Table 6. Headers per playing position for male and female teams (absolute numbers & $M \pm SD$)

	Trainings		Matches	
	Boys	Girls	Boys	Girls
Defender	44 (4.40 $\pm$ 3.24)	53 (6.63 $\pm$ 15.14)	92 (9.20 $\pm$ 4.49)	61 (7.63 $\pm$ 2.67)
Midfielder	31 (3.10 $\pm$ 3.07)	48 (6.00 $\pm$ 15.38)	102 (10.20 $\pm$ 6.65)	79 (9.88 $\pm$ 4.09)
Striker	29 (2.90 $\pm$ 3.14)	48 (6.00 $\pm$ 15.38)	41 (4.10 $\pm$ 1.92)	31 (3.88 $\pm$ 2.95)
Goalkeeper	0	0	0	0

Head injuries

No head injuries were recorded during either training sessions or matches.

Discussion

The aim of the present study was to investigate the frequency, types, and characteristics of headers among youth football players (U16) during both training sessions and matches, estimate the associated mechanical load, and examine the incidence of head injuries. Our first finding was that there were statistically significant differences between boys and girls in the IR of headers during training, with boys performing more; however, no such differences were found during match play. Similar to Beaudouin et al. (2020), our data also showed that headers were generally more frequent in match play than in training sessions, likely reflecting behavioural adaptation under competitive pressure. The frequency of headers in boys' practice (10.40 $\pm$ 7.52) was higher than that reported by Koerte et al. (2017) (7.2 $\pm$ 6.1) whose research had a sample consisting of male players between 13-19 years old. On the other hand, it was lower than that mentioned by den Hollander & Gouttebarger (2023) for their 16 female participants of 14-18 years old, who recorded 11 headers per player (when taking into account an outlying session) and two headers per player when excluding that session from analyses. Considering that our study also identified an outlier session in which a single female team recorded 132 headers, we concur with den Hollander and Gouttebarger (2023) that such instances highlight the significant influence of training session design on players' exposure to heading. These findings reinforce the need to educate coaches on how to structure training in a way that limits excessive heading, in order to mitigate the potential risks associated with repetitive head impacts on brain health.

Regarding IR of headers during matches, a notable comparison can be made with the large-scale study by Sandmo et al. (2020), which quantified heading exposure during an international youth football tournament involving players aged 10–19, according to age category. Drawing from their tabular data and calculating the IR of headers regarding U15 and U16 players, their results are comparable to ours (IR: 2269 for U15 boys and 2.360 for U16 boys; 1429 for U15 girls and 1868 for U16 girls). In contrast, other observational studies (Kaminski et al., 2008) reported heading frequencies notably lower than ours, reporting 1 ($\pm$ 1.3) header per game in female players between 13-18 years old. These findings highlight that heading frequency can vary considerably based on coaching strategies and style of play.

According to our results, the majority of headers were intentional and executed with the frontal region of the head, indicating sound technique and adequate physical readiness (Langdon et al., 2022). As it has been supported, impacts to the forehead result in reduced head acceleration, whereas those to the top of the head result in greater head acceleration (Blyth et al., 2025). Nonetheless, a considerable proportion of headers—particularly among boys in both training and match contexts—were executed using the parietal area of the head. This may indicate suboptimal technique (Beaudouin et al., 2020; Langdon et al., 2022) as well as increased linear acceleration and rotational velocity (Bradbery, Cairns, & Peek, 2024). These findings underscore the importance of technical instruction and proper body positioning when teaching heading skills in youth football (Beaudouin et al., 2020; Langdon et al., 2022). Interestingly, girls appeared to demonstrate better heading proficiency, as only a small proportion of their training and match headers (6.7% and 8.4% respectively) involved contact with the top of the head—a figure substantially lower than that reported by Harris et al. (2023), who found rates between 29% and 35% among U15 female players. Additionally, no header duels were recorded among girls during training sessions, whereas boys were involved in such actions in 13.46% of all heading instances during training. Given that header duels are widely recognized as one of the most significant risk factors for head injuries in football (Peek et al., 2021), it may be advisable to implement preventative strategies aimed at minimizing their occurrence in boys' training sessions—especially when they are not essential to skill acquisition or game-specific preparation.

Regarding ball flight distance before head contact, although most impacts were classified as low, typically involving ball trajectories of less than five meters, followed by 5-10 m, both boys and girls executed headers after a ball trajectory of more than 10 m, which lead to high-impact headers. Additionally, although the majority of headers occurred during free play—as commonly reported in the literature (Langdon et al., 2022; Peek et al., 2021)—a substantial proportion followed free kicks, primarily during match play and predominantly among boys, where they accounted for 17.87% of all headers. The corresponding percentage among girls, although

lower (8.19%), is not negligible. In both sexes, headers after a corner kick were few. The significance of these findings lies in the fact that the highest impact magnitudes have been reported during purposeful headers following corner kicks (Blyth et al., 2025; Bradbery et al., 2024) and free kicks, which are associated with increased linear and rotational head accelerations (Beaudouin et al., 2020). In contrast, headers following throw-ins tend to produce lower impact forces (Blyth et al., 2025).

Finally, in our study, goalkeepers and strikers exhibited the lowest frequency of headers, suggesting reduced exposure to potential heading-related risks. While goalkeepers consistently show no involvement in heading actions, an observation supported across the literature (Beaudouin et al., 2020), heading frequency among other outfield positions appears to vary (Blyth et al., 2025; Harriss et al., 2019; Langton et al., 2022; Sandmo et al., 2019). Therefore, preventive strategies should be tailored to each team's specific tactical approach, rather than relying on generalized assumptions about positional exposure.

According to these findings, it could be hypothesized that under certain circumstances our participants experienced high head accelerations, which however, is based in theory and not in specific measurements. For this reason, the absence of recorded head injuries in the present study, although encouraging, should not be interpreted as conclusive evidence of safety. Prior research has shown that athletes may exhibit decreased performance on neuropsychological tests even in the absence of diagnosed concussion (Matser et al., 1999; O'Kane et al., 2014). Moreover, subclinical impacts to the head may produce cumulative neurophysiological changes over time (Bailes et al., 2013; Breedlove et al., 2012; Langdon et al., 2022). The potentially cumulative, long-term impact of heading on the brain is difficult to determine prospectively, which limits the availability of high-quality scientific data (Meyer & Reinsberger, 2018; Sandmo et al., 2020).

Conclusions

In conclusion, significant differences emerged between boys and girls in the IR of headers during training, with boys performing a higher number; however, no such differences were found during matches. In both groups, headers were more frequent during matches than in training. Of particular concern was that one female team recorded 132 headers in a single training session—a frequency that may pose a potential risk. Across all conditions, most headers were intentional, executed with the frontal part of the head, and followed a short ball trajectory (less than 5 meters), indicating generally proper technique and reduced head acceleration. Nevertheless, a notable proportion of headers—especially among boys during both training and matches—were made with the parietal region of the head, which may reflect suboptimal technique. Additionally, both sexes, particularly during matches, performed several headers after long ball trajectories (over 10 meters) or following free kicks, both of which are linked to higher impact magnitudes. Importantly, no head injuries were reported during either training or match play, yielding a recorded head injury incidence of zero.

While most headers were performed using sound technique and under relatively low-impact conditions, instances of improper form and potentially hazardous circumstances were observed. As such, the absence of recorded head injuries in this study, although encouraging, should not be interpreted as conclusive evidence of long-term safety. Long-term prospective research studies, in real-life contexts, are warranted to inform current knowledge on the potential risk of headings in the long term. In the absence of high-quality scientific data and since definitive evidence is inconclusive due to conflicting results across different studies, repeated exposure of the brain to mechanical forces should still be considered a potential risk factor of neurodegenerative disease. For this reason, improving heading technique, limiting the number of headers during training, and avoiding potentially high-risk actions—such as header duels—may serve as protective measures for young players.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT (OpenAI) for support in proofreading and translation of the text. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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