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The Comparison of Brain Volume in Soccer and Non-soccer Players and Evaluation of the Impact of Repeated Heading History: Case-control Study

Hossein Dadgar[1], Abdolhamid Daneshjoo[2], Mansour Sahebozamani[3], Omid Esmaeili[4], Mona Kharaji[5]

Original Article

Abstract

Introduction: Heading is a technique by which a player uses an unprotected head to intentionally hit the ball and direct it during match. There are growing concerns about the negative impact of repetitive hits to head in heading skill. The present study endeavored to compare the brain volume in soccer players, futsal players, and non-athletes. This study examined the role of heading in the Evans' index as well.

Materials and Methods: Sample consisted of 83 healthy men (55 professional athletes: 30 soccer and 25 futsal players, and 28 non-athletes). Athletes were purposively selected by HeadCount-2w questionnaire from among active soccer and futsal players in the professional league of Hormozgan Province, Iran, and non-athlete samples were randomly selected from those referred to the magnetic resonance imaging (MRI) center of Persian Gulf Hospital in Bandar Abbas, Iran. Evans' Index was employed to assess brain volume. Analysis of variance (ANOVA) was used to compare the means of the groups.

Results: Mean exposure in soccer and futsal players (match or exercise and the possibility of being in a heading position) was 343.40 ± 49.99 and 352.40 ± 44.84 sessions per year, respectively, and the mean number of headings per year in soccer players was 1632. The mean Evans' index was 0.248 ± 0.021 in soccer players, 0.247 ± 0.020 in futsal players, and 0.251 ± 0.018 in non-athletes. All the samples had a normal Evans' index. The results of ANOVA showed no significant difference between Evans' index of soccer and futsal players and non-athletes (P = 0.76, $F_{(2)} = 0.272$) and between Evans' index in different playing positions (P = 0.47, $F_{(2)} = 0.772$).

Conclusion: The Evans' index in Iranian soccer and futsal players playing in Hormozgan League was probably not affected by subconcussive impact of heading. Nevertheless, it seems likely that the index may be affected by exercise and physical activity. Further researches are recommended.

Keywords: Evans' index; Brain volume; Soccer; Heading; Head

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Introduction

Heading is a technique in football in which the athlete consciously uses his head to hit the ball. The nature of the head impact that occurs in this type of hits is different from the hits that occur in other sports such as martial arts (hand or foot collision). Professional football players head an average of 6 to 12 times per game; it is estimated that on average a footballer heads the ball more than 5,000 times during a 15-year professional playing period; While the soccer ball weighs about 400 to 450 grams and often moves at a speed of 85 kilometers per hour and sometimes more (1). This condition causes between 3500 and 8500 subconcussive traumas for a football player during

1- PhD Student, Department of Sports Injuries and Corrective Exercises, Shahid Bahonar University of Kerman, Kerman, AND Instructor, Department of Sports Sciences and Physical Education, Bandar-e Lengeh Branch, Islamic Azad University, Hormozgan, Iran
2- Associate Professor, Department of Sports Injuries and Corrective Exercises, School of Sports Sciences, Shahid Bahonar University of Kerman, Kerman, Iran
3- Professor, Department of Sports Injuries and Corrective Exercises, School of Sports Sciences, Shahid Bahonar University of Kerman, Kerman, Iran
4- Assistant Professor, Department of Neurology, Shahid Mohammadi Hospital, Hormozgan University of Medical Sciences, Bandar Abbas, Iran
5- Assistant Professor, Department of Radiology, Shahid Mohammadi Hospital, Hormozgan University of Medical Sciences, Bandar Abbas, Iran
Corresponding Author: Hossein Dadgar, Email: rokhsareh.hosseindadgar@gmail.com

the play period (2). With these blows to the head, a sudden decrease and increase in acceleration (linear or angular) is imposed on the brain inside the skull (3). As a result of this decrease and increase in acceleration, neurons, glial cells, and blood vessels may become stretched. Therefore, these stretches may disrupt the cellular nutrition system and eventually degenerate brain cells, which can eventually lead to a reduction in brain volume (4). In sports such as karate, boxing, hockey, and football, where frequent hits are inflicted on the head in various ways, a brain volume decrease has been reported (5).

Brain volume can be measured using a variety of indicators such as Bicaudate ratio (BCR), Huckman Number (HN), Cella media index, Third ventricle ratio, Ventricle index (VI), Frontal subarachnoid ratio, Four cortical sulci ratio, Cistern ambiens ratio, Temporal Horn Ratio, and Suprasellar Cistern Ratio (6), one of the most important of which is the assessment of changes in the brain ventricular volume objectively (7). The brain ventricular volume can be measured by quantitative proportions, one of which is Evan's index, which can be used to distinguish between normal and abnormal ventricular volume (8-11). Due to the ease of calculating this index and the lack of need to special software for this purpose, Evan's index is widely used as an indirect but reliable indicator of the brain ventricular volume (12,13). This index has been proposed by Evans (14) with values between 0.20 and 0.25, between 0.25 and 0.30, and values over 0.30 indicating normal status, the borderline increase in ventricular volume, and abnormal brain and pathological conditions, respectively (11,15,16). However, there are documents that indicate values above 0.3 and normal ventricular volume (17). Missori et al. concluded in their study that Evan's index above 0.30 indicates an underlying neurological disease in each individual (18). On the other hand, Brix et al. found that there is a wider range of Evan's index in healthy older adults and that the cut-off point of this index in men is values above 0.30 (19).

The results of studies have shown that the brains of athletes in sports in which frequent impacts are imposed to the head, suffer from atrophy and brain volume reduction (20), detectable structural differences in the brain (21), differences in the integration of white matter volume (22), and abnormal states of the white matter (23). Additionally, neurocognitive changes due to heading have been reported at the end of the football season (24). Some studies have reported that changes in brain volume due to central nervous system (CNS) disorders can adversely affect indicators such as balance (25), postural control (26), and reaction time (28, 27), which can lead to decreased levels of athlete performance, and since these indicators are considered as risk indicators of sports injury, are likely to predispose to further injuries (29). In the study of Adams et al., which examined the extent and cause of brain atrophy in footballers, a significant reduction in the gray matter volume was reported in the footballer group compared to the control group, and they concluded that the cause of this atrophy was frequent hits to the head (20). The results of the Witol and Webbe study, which aimed to investigate the effect of head hits in football on neurological and mental disorders, showed that players who had more head hits during the sport, were weaker than the control group in concentration, awareness, accuracy, perceptual ability, and functional activities of the mind (30). Sortland and Tysvaer cited frequent hits to the soccer ball as the main cause of cerebellar atrophy in retired Norwegian national football players, and noted that there was a significant association between the brain central and cortical atrophy and heading. In their study, players who were identified as headers (players with a high number of head hits) had a higher rate of cortical atrophy (31). In a study examining changes in ventricular volume using Evan's index, Jordan et al. reported that there was no significant difference in brain volume between footballers and non-soccer (athletics) group (32). On the other hand, Oliveira et al., by examining the thickness of the cerebral cortex and the gray matter volume, concluded that heading was not associated with a decrease in brain volume (33).

In injury and incident prevention models such as Van Michelin or Translating Research into Injury Prevention Practice (TRIPP), the preliminary steps include the prevalence measurement and etiology of injuries. In Iran, no data have been provided on the mechanism of heading and brain volume in Iranian footballers. Since research has shown that perhaps one of the reasons for the decrease in brain volume is frequent hits to the head, and given that heading skills are likely to lead to frequent head hits, the aim of this study was to investigate brain volume and the possible effect of heading on it in Iranian footballers in the Class of Hope [18 to 21 years old according to Federation Internationale de Football Association (FIFA) age categories] and compare it in futsal players and non-athletes. Since the purpose of this study was to investigate the effect of frequent hits to the head given the heading skill and technique in footballers, the sport of futsal was selected as a control sample of football; Because the skills and techniques (shoot, pass, dribble) and level of physical activity in this sport are closer to football than other sports, but do not use head hits; Although the two fields are completely different in terms of energy system, the factors that were affected by the physiological differences between the two sports, were not considered as research variables and did not affect it.

Materials and Methods

This was a causal-comparative and retrospective study with a quasi-experimental case-control design that was conducted in the period of August 2020 to May 2021. The research method was approved by the ethics committee in the research of Shahid Bahonar University of Kerman, Kerman, Iran. The sample consisted of 83 healthy men [55 professional athletes (30 soccer players and 25 futsal players) and 28 non-athletes] in Hormozgan Province. The athlete subjects were purposively selected using the HeadCount-2w, a web-based two-week-recall questionnaire on soccer an among footballers and futsal players in the Hormozgan Province Professional League, and the non-athlete subjects were randomly selected from clients referred to the Magnetic Resonance Imaging (MRI) Center of Bandar Abbas Persian Gulf Hospital, Iran.

The HeadCount-2w scale is a self-reporting scale (34,35) in which a person announces the number of heads he/she has hit in training and competitions in the past two weeks. Annual data (number of heads per year) is estimated based on these biweekly reports. With the coordination of the managers and coaches of the active sports clubs in the provincial league, the questionnaire was distributed among the target community and after at least two weeks, it was collected. Among the people who completed the questionnaire, on the basis of the inclusion criteria, the individuals were scheduled to have an MRI. The control samples were selected from among the clients in coordination with the deputy director of treatment of the Social Security Organization (trustee of the MRI center) and obtaining permission to use hospital data according to the checklist provided to the head of the MRI center (items such as age, gender, professional sports, alcohol, and tobacco). The compact disks of the data of the selected individuals were examined by a radiologist and the non-atrophic individuals were visited by a neurologist. In case of qualifying for the inclusion criteria, the brain volume indices were measured and recorded. If the exclusion criteria were observed, the person was excluded. The control group was matched only in terms of age and exercise.

The sample size was determined using G-Power software (G*Power 3.1.9.7 freeware, University of Düsseldorf, Düsseldorf, Germany) (total sample size = 82 with test power = 0.95, α = 0.05, and effect size = 0.40). The sample size determined was confirmed in the research background (31,32). The validity of the questionnaire [intraclass correlation coefficient or (ICC)] used was reported to be 0.75 (34) and 0.85 (35).

The initial examination of the samples was performed by the neurologist, and if the exclusion criteria were observed, the sample was excluded from the study. The specialist was not aware of the grouping of samples and MRI recording was performed only for people who qualified for the inclusion criteria, and the MRI images of each person were examined independently by three radiologists. Since the Evan's index is an age-influenced index, in order to control the effect of age on brain volume, data were collected from young athletes (Hope Class) to determine whether, in parallel with age, small and frequent heading hits in people with a history of professional sports lead to a change in the components of this index. The use of this group of athletes also makes it possible to plan for preventive interventions and future studies if statistically significant results are observed, in order to prevent possible future clinical problems.

The inclusion criteria included the age range of 18-21 years (Hope Class based on FIFA age categories), regular weekly training (at least three sessions per week) for footballers and futsal players, inactivity in the form of membership and sports training in the province football and futsal clubs for the control group, and recording a non-zero number in counting the number of heads for football players and a zero number for futsal players and non-athletes. Moreover, alcohol consumption, smoking, history of neurological injuries such as epilepsy, seizures, and similar problems were considered as the exclusion criteria. The inclusion and exclusion criteria were determined through interviews with the subject in the form of a visit by the neurologist and examination of the MRI images by the radiologists. If the consent form was not completed and the dissatisfaction was declared, the person was excluded from the study.

Imaging method: In the second stage, MRI was taken from the brains of people who were eligible to enter the study. Using the MRI device of the Persian Gulf Hospital of Bandar Abbas (1.5 Tesla Power, Philips, Netherlands) with T2 weighting in the SPGR sequence of the axial view, the brain of the samples was imaged. The images were examined by the three radiologists and the brain volume indices were recorded by all three in millimeters. The mean of the recorded sizes was considered as the final size in the analysis. None of the experts were aware of the grouping of the subjects. The Evan's index was used to assess brain volume. This index was calculated from the ratio of the maximum bilateral width of frontal horns (MFH) to the maximum inner cranial width (MIC) (31). These two indices were extracted from the MRI images by the Measure tool and recorded in millimeters (Figure 1).

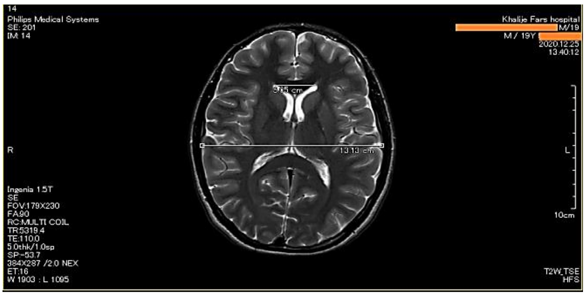

Figure 1. Extraction of indices used to calculate the Evan's index

The annual data were estimated based on the weekly self-report data. For one year of professional activity, 34 weeks of matches were considered with the 18-team league, excluding national and friendly matches. Each competition averaged 1.5 hours and each training session 2 hours. The incidence ratio was calculated by dividing the number by the total. The Shapiro-Wilk test was used to evaluate the normality of the data distribution and the analysis of variance (ANOVA) test was used to compare the means of the groups. The inter-rater reliability of the consistency of the radiologists' comments was reported using the ICC test. Data were analyzed using SPSS software (version 25, IBM Corporation, Armonk, NY, USA). $P < 0.05$ was considered as the significance level.

Results

The results of consistency of the radiologists' report are presented in table 1.

The demographic and professional information of the samples is presented in table 2. The information of all participants was fully collected. The power of the present study was 0.90. the athlete subjects had professional activity for 3 to 6 years at the time of the study and 56.7% of footballers played as defenders.

A total of 10302 exposure sessions per year were reported for footballers with a ratio of 9.9% for the match and 90.1% for training, 48960 heads with a ratio of 10% in the match and 90% in training. The average number of heads per match and in each training session was respectively 4.83 and 14.43 heads (19.26 per week of exposure). The total number of exposures per year for futsal players was 8806 sessions with a ratio of 9.6% for competition and 90.4% for training. The defenders reported the highest number of heads compared to other positions (Table 3). 0.75% of attackers, 41.2% of defenders, and 0.40% of midfielders had a heading history of more than the average of the group. The selected futsal players did not have head hits to enter the study.

Table 1. Inter-rater reliability in components measured to calculate Evan's index

Component	ICC	CI (95%)	P
MFH	0.993	0.983-0.996	< 0.001
MIC	0.998	0.997-0.999	< 0.001

MFH: Maximum Bilateral Width of Frontal Horns; MIC: Maximum Inner Cranial Width; ICC: Intraclass correlation coefficient; CI: Confidence interval

The average Evan's index was 0.248 ± 0.021, 0.247 ± 0.020, and 0.251 ± 0.018 in footballers, futsal players, and non-athletes, respectively, as 0.241 ± 0.023 in attackers, 0.251 ± 0.018 in defenders, and 0.243 ± 0.029 in midfielders. In terms of cut-off point (0.3), all subjects had normal Evan's index. Non-athletes from other groups and defenders from other positions reported higher Evan's index, but the results of ANOVA test showed that the football players, futsal players, and non-athletes differed in the Evan's index ($P = 0.760$, $F_{(2)} = 0.272$), and there was no significant difference in the Evan's index in different positions of the game ($P = 0.470$, $F_{(2)} = 0.772$ (2)) (Table 4).

Discussion

The aim of this study was to evaluate the brain volume in soccer players, futsal players, and non-athletes. The study examined the association and possible effect of heading on brain volume in which the Evan's index was used to assess brain volume.

Table 2. Description of the professional characteristics of the participants

	Age (years) (Mean ± SD)	History (year) (Mean ± SD)	Competitions per year (exposure session)	Practice per year (exposure session)	Exposure per year (Exposure session)* (Mean ± SD)
Footballers (n = 30)	19.20 ± 1.10	4.36 ± 1.03	34	309.40 ± 49.99	343.40 ± 49.99
Futsal players (n = 25)	19.32 ± 1.11	4.28 ± 0.98	34	318.24 ± 44.84	352.40 ± 44.84
Non-athletes (n = 28)	19.21 ± 1.13	0	0	0	0

*An exposure session means a competition or training session and the possibility of being in a head position.

Table 3. Description of the frequency of heading in terms of playing position in footballers (number)

Number of heads	Professional position	Statistical index	Per week	Per year (competition)	Per year (practice)	Per year (total)
Total	-	n	19.26 ± 3.61	164.33 ±40.01	1467.66 ±350.97	1632.00 ±344.77
Footballers (n = 30)	Attacker (n = 8)	Mean ± SD	18.37 ± 1.76	144.50 ±35.19	1428.00 ±224.79	1572.50 ±199.70
		Median	18.50 (21-16)	136.00 (204-102)	1530.00 (1632-1020)	1649.00 (1768-1224)
	Defender (n = 17)	Mean ± SD	20.11 ±3.83	184.00 ±36.18	1458.00 ±407.62	1642.00 ±402.78
		Median	20.00 (26-14)	170.00 (238-102)	1428.00 (2142-1020)	1598.00 (2244-1156)
	Midfielder (n = 5)	Mean ± SD	17.80 ±4.81	129.20 ±15.20	1564.00 ±353.33	1693.20 ±361.74
		Median	15.00 (24-14)	136.00 (136-102)	1360.00 (2040-1224)	1496.00 (2176-1326)

SD: Standard deviation

The results showed that there was no significant difference between the mean of Evan's index in the studied groups and in different positions. In previous studies, the values of this index have been reported differently in different age groups, races, and ethnicities (36-39). The mean Evan's index in the study of Dzefi-Tettey et al. was 0.211 ± 0.007 for the age group under 22 years (36). Dhok et al., Polat et al., and Sari et al. reported mean values of 0.257 ± 0.024 for ages under 20 (37), 0.290 ± 0.210 for ages 18 to 30 (38), and 0. 242 ± 0.005 in 18-year-olds, respectively (39), all of which had the same age range as the present study. In the present study, the mean of this index in terms of cut-off point in all groups was in the normal range and no significant difference was observed in any of the groups. The Evan's index is an age-influenced index, and the study groups were age-matched, which may justify the lack of difference among the age groups.

In previous studies (36-39), no sample similar to the present study was found. All these studies aimed at finding and reporting normal Evan's index in the community of that country (36-39). The target population of the present study was athletes, and no similar study was found to report the Evan's index in athletes in this age group (especially in football and futsal). Reasons for differences in reports can be racial, demographic, and ethnic factors. Evan’s index differs in different races, and since the Asian races have a smaller biastrionic breadth (36), this is probably one of the reasons why the Evan’s index is lower in Iranian samples. The normal range of this index was not available in domestic samples to compare this index with the Iranian community.

The results of the present study did not match the findings of studies by Adams et al. (20), Lipton et al. (23), Koerte et al. (22), and Koerte et al. (40) which examined the relationship between heading and brain volume in footballers and reported changes in brain volume. The difference in results may be due to differences in the scale, criteria, and index used to determine brain volume. The criterion for assessing brain volume in the study of Adams et al. was gray matter volume (20). This criterion was the white matter volume in the studies of Lipton et al. (23) and Koerte et al. (22) and the cerebral cortex thickness (40) in the study of Koerte et al. The Evan's index was employed in the present study and the results were consistent with those of studies by Oliveira et al. (33), Kenny (41), Kemp et al. (42), and Jordan et al. (32) who reported no change in brain volume in footballers. In their study, Jordan et al. who examined changes in ventricular volume using the Evan's index, found that there was no significant difference in brain volume between footballers and non-soccer team (32). In the study of Oliveira et al., the brain volume scale was considered as intracranial volume (33).

Table 4. Analysis of variance (ANOVA) test results for brain volume indices

Variable	Group (n)	Mean	Degree of freedom	F	P	η^2
MFH	Footballers (n = 30)	31.550 ±2.250	2	0.374	0.69	0.009
	Futsal players (n = 25)	31.620 ±2.300				
	Non-athletes (n = 28)	32.010 ±2.010				
MIC	Footballers (n = 30)	127.600 ±5.320	2	0.034	0.97	0.001
	Futsal players (n = 25)	127.960 ±5.510				
	Non-athletes (n = 28)	127.670 ±5.070				
Evan’s index	Footballers (n = 30)	0.248 ±0.021	2	0.272	0.76	0.007
	Futsal players (n = 25)	0.247 ±0.020				
	Non-athletes (n = 28)	0.251 ±0.018				

MFH: Maximum Bilateral Width of Frontal Horns; MIC: Maximum Inner Cranial Width

Limitations

One of the limitations of the present study was the lack of similar studies, neither domestic nor international, to compare the study hypotheses. Another limitation was the small number of samples, which, despite planning and coordination with clubs, the spread of the coronavirus disease 2019 (COVID-19) did not allow evaluation in larger samples; However, the study power analysis showed that this issue did not affect the validity of the reported results. On the other hand, these results were obtained only in one geographical area, one race, in the provincial professional league and in young active samples compared to non-athlete samples, and it may be problematic to extend the results to other geographical areas, other races, other leagues, and other age groups of footballers.

Recommendations

Given the validity and breadth of use of the Evan's index, reporting the normal value of this index in different age groups, in both sexes, and in different athletes and professions, can be valuable and allow the results of subsequent studies to be compared with each other and with those in healthy individuals. Research into the effects of heading on brain structure and function has yielded interesting results, but the findings are not yet conclusive. Some studies with brain imaging techniques have examined the possible association of heading and abnormalities and structural and functional disorders of the brain in football players (20-33) and some biochemical markers of brain damage in these individuals (43). Both neuroimaging and biomarker technologies are promising topics in this field of study that are suggested to evaluate the effect of heading.

Conclusion

The aim and approach of the present study was to evaluate the brain volume in soccer players, futsal players, and non-athletes. The results indicated that peer and homogeneous groups of 18 to 21 years old, which are known as the Hope Class in the age category of football, did not have a significant difference in terms of brain volume. Given the findings, football heading in young professional footballers probably has no effect on Evan's brain index, and ventricular volume, which represents brain atrophy, is not affected by heading, but exercise and professional activity may affect this index. This field of research needs further investigation.

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Authors' Contribution

Study design and ideation: Hossein Dadgar, Abdolhamid Daneshjoo, Mansour Sahebozamani
Study support, executive, and scientific services: Hossein Dadgar, Abdolhamid Daneshjoo, Mansour Sahebozamani
Providing study equipment and samples: Hossein Dadgar, Omid Esmaeili, Mona Kharaji
Data collection: Hossein Dadgar, Omid Esmaeili, Mona Kharaji
Analysis and interpretation of results: Hossein Dadgar, Omid Esmaeili, Mona Kharaji
Specialized statistical services: Hossein Dadgar, Abdolhamid Daneshjoo
Manuscript preparation: Hossein Dadgar, Abdolhamid Daneshjoo, Mansour Sahebozamani, Omid Esmaeili, Mona Kharaji
Specialized evaluation of manuscripts in terms of scientific concepts: Hossein Dadgar, Abdolhamid Daneshjoo, Mansour Sahebozamani, Omid Ismaili, Esmaeili, Mona Kharaji
Confirmation of the final manuscript to be sent to the journal office: Hossein Dadgar, Abdolhamid Daneshjoo, Mansour Sahebozamani, Omid Esmaeili, Mona Kharaji
Responsibility for maintaining the integrity of the study process from the beginning to the publication and responding to the referees' comments: Hossein Dadgar, Abdolhamid Daneshjoo, Mansour Sahebozamani, Omid Esmaeili, Mona Kharaji

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Conflict of Interest

The author of the present study, on behalf of all contributors, declares that the authors have no conflict of interest in publishing the study results.

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