Doctoral thesis

PSYCHOLOGY OF TRAUMATIC BRAIN INJURY

ROLE OF PROSPECTIVE AND RETROSPECTIVE EXAMINATIONS IN PREVENTION OF HEAD TRAUMA

Viktória Tamás

Department of Neurosurgery, University of Pécs

Doctoral school of clinical neurosciences (D221)

Head of Doctoral School: Sámuel Komoly, M.D., Ph.D., D.Sc.

Doctoral program of Neurosurgery (B-4/2014)

Program leader: András Büki, M.D., Ph.D., D.Sc.

Supervisor: András Büki, M.D., Ph.D., D.Sc.

University of Pécs, Medical School

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I. Retrospective assessment of „*Young Male Syndrome*" phenomenon among patients with severe traumatic brain injury

Introduction

Severe traumatic brain injury (sTBI) represents a major epidemiological problem: the WHO estimates that at the end of this decade it will belong to the three most frequent causes of death. Distinctively, 69 million individuals worldwide are affected by traumatic brain injury annually, regardless of severity, including an estimated 5.48 million new cases of severe head injuries per year, comprised of interpersonal violence, traffic accidents and falls being the leading causes according to international epidemiological analyses. In Hungary, apart from physical abuse, traffic accidents and falls are also responsible for the incidence of serious head injuries.

In various statistical databases, the male/female ratio of TBI cases ranges from 3:1 to 5:1, with a peak age of 35–50 years. The burden of these injuries is also reflected in economic consequences as it is primarily affecting the young, active–predominantly male–population. The proportion of physical forces as well as the causes evoking and being responsible for TBI display a broad variation between countries worldwide, reflecting a clear tendency of increased occurrence of TBI in the elderly primarily related to falls. Nevertheless, epidemiological studies have demonstrated that road traffic accidents and interpersonal violence still should be considered as major causes of TBI particularly in the young. In Hungary, falls and auto-vehicular accidents are the leading causes of sTBI. In both age groups, these serious injuries also bear a proportionate risk of fatal outcome.

For example, the mortality rate of young European people due to accidents was 17/100,000 cases in 2005. 41% of severe head injuries in Hungary are fatal, compared to only 20-30% in the US, which may be due to low rates of neurosurgery on-call, routine follow-up and lack of adequate rehabilitation care.

In concordance with international epidemiological surveys, the most important risk factors associated with sTBI are the following: intoxication with alcohol or drugs, lack of protective devices, violation of traffic rules– particularly speed limits.

Males, compared to females, are characterized by more aggressive and competitive behavior in practically all cultures and ages. They tend to focus on temporary benefits and gains from their actions rather than long-term consequences and costs. Higher risk taking is particularly characteristic for the male population between the ages of 15–35 years, the time when intrasexual competition is the strongest. This pattern of risk taking is often referred to as Young Male Syndrome (YMS). The higher willingness of males to engage in risky behavior also manifests in criminal acts. The analysis of law-breaking behavior in Detroit revealed that in robberies and assaults as well as in murders, both victims and offenders were primarily non-related, unemployed, young (18–40 years), single males. In a more recent study, Farsang and Kocsor (2016) analyzed Hungarian and Australian homicide data to investigate whether the sex and age distributions of both parties correspond to the former findings. They found that both victims and criminal offenders were predominantly males but only the offenders belonged to the young age group (18–34 years).

1. Hyphotheses

In our retrospective study we sought to test whether the age when the reproductive competition between males peaks corresponds to the age when the incidence of severe injuries is the highest. By using a clinical database, we also assessed the riskiness of the underlying causes in the different age groups.

- On the basis of the above-detailed etiology of sTBI, and taking into account that risk-taking propensity of males is the highest in adolescence and young adulthood, we predicted that males between the ages of 15–35 years acquire sTBI from riskier behaviors (Hypothesis 1), which also leads to higher mortality rates, compared to male members of other age groups and females at any age (Hypothesis 2).
- We also expected that after acute alcohol intoxication, the aforementioned patterns of risk-taking behavior and mortality rates would be even more pronounced. Our prediction was that younger males (15–35 years) who consume alcohol on the day of injury could suffer sTBI from riskier behaviors, whereas intoxicated older males and females at any age suffer severe brain trauma from less risky activities (Hypothesis 3). In addition, we assumed that males who were alcohol intoxicated on the day of injury would have the highest external mortality rate associated with their riskier behavior (Hypothesis 4).
- The incidence rates obtained in our study sample in terms of the distribution of gender and injury conditions are hypothesized to support the published data regarding international literature (Hypothesis 5).

To test whether the evolutionary explanation of the demographic distribution of brain injuries was accurate, we wanted to compare different statistical models to determine which factors (age, sex, alcohol intoxication) contribute the most to risk-taking behavior and mortality.

2. Methods

2.1. Subjects

Subjects The study group consisted of consecutive patients with sTBI (N = 374) registered with the Pecs Severe Traumatic Brain Injury Database, with the inclusion criteria of post-resuscitation GCS-score (Glasgow Coma Scale) <9. Data and information of patients were retrieved from the database in 2013. The data on age, sex, injury circumstances, and alcohol consumption were registered between 2002 and 2012. All experimental procedures were carried out with the permission and under the control of the Institutional Review Board of the University of Pecs (IRB number: IRB00003108).

2.2. Determination of Age Groups and Sex ratio

The group of 374 patients (mean age at the time of injury: 54.0 years, SD = 20.27, between 1 and 92 years) with sTBI consisted of 90 females (mean age: 62.4, SD = 21.81) and 284 males (mean age = 51.3, SD = 19.04). The definition of being “young” varies across publications on YMS (e.g., 0–35, 18–40, etc.), however, we defined 4 age groups to approximate the classification of both evolutionary and clinical studies (see Table 1): group 1 under 15 years, group 2 between 15 and 35 years (target population according to our hypothesis), group 3 between 36 and 65 years and group 4 above 65 years. As the low number of patients under 15 precluded any valid statistical assessment, detailed analysis was performed over this age limit only, so the cohort in the analyses consisted of 365 patients.

2.3. Classification of Risk Level

We aimed to assess the degree of risk-taking behavior which led to severe brain injuries. University students (N = 57, 47 females, 10 males; mean age = 22.1, SD = 4.81) were recruited to judge the riskiness of injury-circumstances on a 5-point Likert-scale (1 = non-risky, 2 = slightly risky, 3 = moderately risky, 4 = considerably risky, 5 = highly risky). All students took part voluntarily. To promote the understanding of the task, we provided and discussed the definition of risk-taking propensity and a couple of examples of different risky activities leading to sTBI. Thus, the students could estimate the riskiness of the behavior behind the injuries, while avoiding mixing it up with the riskiness of the injury in a medical sense. We defined risk-taking behavior as “a person is consciously seeking situations which are accompanied by severe consequences”.

The injury-circumstances varied widely. Accordingly, these examples only gave some direction to help the students make decisions about the degree of riskiness of injury-circumstances. Furthermore, we did not mention examples about some risktaking behaviors such as gambling or unsafe sex because these were not relevant for our examination. Since the sex ratio of the university students was not equal, we performed an independent samples t-test and a Pearson correlation using SPSS 20.0 to test whether this had any effect on the evaluation of riskiness considering the injurycircumstances. According to the results ($r = -0.021$; $p > 0.05$; $t = 0.155$; $p > 0.05$), the sex distribution did not affect the rating of riskiness of the injury-circumstances. The Cronbach’s alpha of estimations given by the raters was 0.977. This is critical, because the very essence of the YMS is that young men have a higher threshold for evaluating an event as risky, and, in general, they have higher impetus for sensation seeking. Because of that, the skewed distribution of men and women might have potentially distorted the content of the categories. Among the participants who rated the descriptions of events, there was no sign of the aforementioned pattern; both men and women had fairly the same subjective feelings about the riskiness of behaviors that were followed by sTBI. Following the evaluations, three groups of riskiness were established with K-means Clustering (with SPSS 20.0): **Cluster 1** consisted of low risk injury-circumstances, **Cluster 2** included moderate risk injury-circumstances and **Cluster 3** contained high risk injury-circumstances.

3. Results

3.1. Determination of the best fitting models

Determination of the Best Fitting Models We prepared a series of Generalized Linear Mixed Models (GLMM, SPSS 24.0) to assess which of the potential factors– sex, age, alcohol intoxication–, and the interactions among them, contribute the most to risk-taking behavior, and mortality. First, our intention with the first two models was to decide whether we should include any random factors in the model. For Model 1 (Table 1), we used riskiness as the target variable with a multinomial probability distribution and generalized logit link function, age group, sex and alcohol intoxication as predictors, and year of injury as a random variable. For Model 2 (Table 2), we used the same target and predictor variables without any random variable. Both models were significant, but the higher Akaike Information Criterion (AIC) of Model 1 (value: 3354.372) showed that this was not as good as Model 2 (AIC= 85.684).. Hence, as the latter did not include any random variable, we did not incorporate random factors in the subsequent models.

Model 1			**F**	**df1**	**df2**	***p***	**Exp. Coefficent**
Model fit	Akaike Corrected IC	3354.372					
	Accuracy	72.1%					
Fixed effects	Corrected model		8.566	8	355	< **.001**	
	Age groups		4.219	4	355	**.002**	
	Sex		6.560	2	355	**.002**	
	Alcohol int.		21.581	2	355	< **.001**	
Fixed coefficients (high-low/high-moderate)	Intercept					< **.001** / .014	189.520 / 8.881
	15-35					< **.001 / .050**	.097 / .325
	36-65					**.022** / .126	.291 / .460
	65+						
	Male					**.005** / .302	.104 / .437
	Female						
	Alcohol int.					< **.001** / .902	.008 / 1.045
	Not Alcohol int.						
Coefficients in blank rows are set to zero because these are redundant. P-values in bold are significant on a $p < 0.05$ significance level.							

Table 1. Model 1 with year of injury as random variable and riskiness as target variable.

Model 2			**F**	**df1**	**df2**	***p***	**Exp. Coefficent**
Model fit	Akaike Corrected IC	85.684					
	Accuracy	72.1%					
Fixed effects	Corrected model		5.760	8	355	< **.001**	
	Age groups		2.854	4	355	**.024**	

	Sex		4.417	2	355	**.013**	
	Alcohol int.		14.494	2	355	< **.001**	
Fixed coefficients **(high-low/high-moderate)**	Intercept					< **.001** / .044	189.682 / 8.885
	15-35					**.001** / .108	.097 / .325
	36-65					.059 / .210	.291 / .460
	65+						
	Male					**.021** / .398	.103 / .437
	Female						
	Alcohol int.					< **.001** / .920	.008 / 1.045
	Not Alkohol int.						
Coefficients in blank rows are set to zero because these are redundant. P-values in bold are significant on a $p < 0.05$ significance level.							

Table 2. Model 2 without random variables and riskiness as target variable

Our strategy was to create models with all possible variables and interactions, then to omit those factors from the models which were the least significant, one after the other, until a significant model with significant predictors was determined. We started the iterations from four different models: Model 3 with riskiness as the target variable, and age groups and sex as predictors; Model 7 with mortality as the target variable, and age groups, sex and riskiness as predictors; Model 12 with riskiness as the target variable, and age groups, sex and alcohol intoxication as predictors; and Model 14 with mortality as the target variable, and age groups, sex, alcohol intoxication and riskiness as predictors. Thus, we ended up with 31 different models (see Table 3), from which seven significant models were appropriate for the evaluation of our hypotheses.

BEST FITTING MODELS		**1[a]**	**2**	**5**	**6**	**10**	**11**	**13**	**26**	**31**
Célváltozó		R	R	R	R	M	M	M	M	M
Model fit	Akaike Corrected IC	3354.372	85.684	60.803	39.824	71.200	52.024	88.066	56.976	21.212
Fixed effects	Corrected model	**< .001**	**< .001**	**< .001**	**<.001**	**< .001**	**.001**	**<.001**	**.003**	**<.001**
	Age groups	**.002**	**< .001**		**<.001**	**< .001**	**.001**	**<.001**		**<.001**
	Sex	**.002**	**.024**					**<.001**		

	Alcohol int.	**< .001**	**.013**					**<.001**		
	Riskiness					**.014**	.505			
	Age groups x Riskiness					**.030**	.731			
	Sex x Risk.					.218				
	Age groups x sex			**< .001**				**<.001**		
	Sex x Alcohol int.							**<.001**		
	Age groups x Alcohol int.							**<.001**		
	Age groups x Sex x Alcohol int.								**.003**	

R= Riskiness; M= Mortality
[a]Model 1 includes year of injury as a random variable.
Values in bold indicate significant effects ($p < 0.05$).

Table 3. P-values of Variables and interactions of the best fitting GLM Models

3.2. Risky Behavior as the Target Variable

Model 5 (Table 4) suggested that the interaction between sex and age group significantly predicted whether the brain injury was caused by highly risky, moderately risky, or non-risky behavior. However, the exponential coefficients were not significant, so it is not possible to draw precise inferences from this relation. In contrast, Model 6 (Table 5) showed that age group by itself was a significant predictor for the riskiness of behavior at the time of injury. More precisely, the significant exponential coefficients showed that if a patient’s age is between 15 and 35, the chance is about ten times that s/he had suffered brain injury from a highly risky behavior rather than from a low risk behavior, and about three times that the behavior was moderately risky, compared to members of the 36–65 years age group. The relation was similar between the age group of 36–65 and the eldest group with about a five times higher chance for highly risky rather than non-risky behavior. There was no significant difference between highly risky and moderately risky behaviors between these groups.

Model 5			**F**	**df1**	**df2**	***p***	**Exp. Coefficent**
Model fit	Akaike Corrected IC	60.803					
	Accuracy	56.7%					
Fixed effects	Corrected model		3.434	10	353	**< .001**	

	Age groups x Sex		3.434	10	353	**< .001**	
Fixed coefficients (high-low / high-moderate)	Intercept					.998 / .998	3993812637.025 / 347288055.393
	15-35 x Male					.998 /.998	.000 / .000
	15-35 x Female					1.000/ 1.000	1.249 / .000
	36-65 x Male					.998 /.998	.000 / .000
	36-65 x Female					.998 /.998	.000 / .000
	65+ x Male					.998 /.998	.000 / .000
	65+ x Female						
Coefficients in blank rows are set to zero because these are redundant. P-values in bold are significant on a p < 0.05 significance level.							

Table 4. Model 5 without random variables and riskiness as target variable

Model 6			**F**	**df1**	**df2**	***p***	**Exp. Coefficent**
Model fit	Akaike Corrected IC	39.824					
	Accuracy	56.2 %					
Fixed effects	Corrected model		6.748	4	359	**<.001**	
	Age groups		6.748	4	359	**<.001**	
Fixed coefficients (high-low/high-moderate)	Intercept					**< .001/ .001**	15.333/ 4.333
	15-35					**< .001/ .034**	.106/ .303
	36-65					**< .001/** .111	.183/ .447
	65+						
Coefficients in blank rows are set to zero because these are redundant. P-values in bold are significant on a p < 0.05 significance level.							

Table 5. Model 6 without random variables and riskiness as target variable

Considering alcohol intoxication, the predictor variables like age group, sex, alcohol intoxication, and interactions between these resulted in a significant model (Model 13, Table 6). However, the value of the AIC is somewhat higher (88.066), therefore the model is better, if we eliminate the interactions from the model (Model 2). In this case, the exponential coefficients suggested that people in the youngest age group, in contrast to members of the 36–65 group, were ten times more likely to engage in high risk compared to low risk situations that led to sTBI. A similar, significant relation was found for males compared to females, and alcohol intoxicated compared to not intoxicated ones. A non-significant tendency was also present in the comparison of the 36–65 and the eldest age group, suggesting that members in the younger group had about a five times higher propensity for high risk vs. low risk behavior.

Model 13			F	df1	df2	*p*	Exp. Coefficent
Model fit	Akaike Corrected IC	88.066					
	Accuracy	73.7 %					
Fixed effects	Corrected model		161564623.983	18	345	**<.001**	
	Age groups		135.814	4	345	**<.001**	
	Sex		165.920	2	345	**<.001**	
	Alcohol int.		2299285.297	2	345	**<.001**	
	Age groups x Sex		4906046.901	4	345	**<.001**	
	Age groups x Alcohol int.		115986 170.829	4	345	**<.001**	
	Sex x Alcohol int.		314148 75.741	2	345	<**.001**	
Fixed coefficients (high-low/high-moderate)	Intercept					**<.001/<.001**	3397396092.479 / 147712873.586
	15-35					.967 /<**.001**	.876 / .000
	36-65					**<.001/<.001**	.000 / .000
	65+						
	Male					**<.001**/<**.001**	.000 / .000
	Female						
	Alcohol int.					**<.001/ <.001**	.000 /2.424
	Not Alcohol int.						
	15-35 x Male					.683 / **<.001**	.270/ 107509406.062
	15-35 x Female						
	36-65 x Male					**<.001/ <.001**	73856436.793 / 36792950.197
	36-65 x Female						
	a						
	15-35 x Alcohol int.					.753 / <**.001**	.116 / .030
	15-35 x Not Alcohol int.						

	36-65 x Alcohol int.					**<.001** /<**.001**	74671103.801 / .413
	36-65 x Not Alcohol int.[a]	.					
	Male x Alcohol int.					**<.001** / **<.001**	.250 /1.768
	Male x Not Alcohol int.[a]						
[a]Rows with redundant coefficients were removed. Coefficients in blank rows are set to zero because these are redundant. P-values in bold are significant on a p < 0.05 significance level.							

Table 6. Model 13 without random variables and riskiness as target variable

3.3. Mortality as the Target Variable

A significant model to predict the likelihood of death after sTBI can be built by including age group, riskiness, the interaction between age and riskiness, and the interaction between sex and riskiness in a GLMM (Model 10, Table 7). This model showed that patients in the 15–35 age group were about nine times more likely to survive than those in the 36–65 group, and the latter had about three times higher survival rates compared to the eldest patients. The exponential coefficients for the interaction between age group and riskiness showed that patients between 15 and 35 years had a three times higher chance for survival if the accident happened from a moderately or highly risky behavior compared to a low risk behavior. Neither coefficients for the age group-riskiness interaction, nor the fixed effects of sex and riskiness interaction, nor for fixed coefficients of riskiness were significant. The model had a better fit if we omitted sex-riskiness interaction (Model 11, Table 8). In this case, age group was the only significant fixed effect and fixed coefficient, showing that people in the youngest group had a nine times higher survival chance than those in the 36–65 group.

Model 10			**F**	**df1**	**df2**	***p***	**Exp. Coefficent**
Model fit	Akaike Corrected IC	71.200					
	Accuracy	64.7 %					
Fixed effects	Corrected model		13.081	11	353	< **.001**	

	Age groups		36.558	2	353	< **.001**	
	Riskiness		4.347	2	353	**.014**	
	Age groups x Riskiness		2.704	4	353	**.030**	
	Sex x Riskiness		1.486	3	353	.218	
Fixed coefficients (no-yes)	Intercept					.999	.000
	15-35					**<.001**	.115
	36-65					**.005**	.306
	65+						
	Low risk.					.999	711218554.421
	Moderate risk.					.999	473510614.812
	High risk.						
	15-35 x Low risk.					**.036**	2.992
	15-35 x Moderate risk.					.453	1.525
	15-35 x High risk.						
	36-65 x Low risk.					.418	1.431
	36-65 x Moderate risk.					.584	.771
	36-65 x High risk.						
	[a]						
	Male x Low risk.					.341	1.140
	Female x Low risk.						
	Male x Moderate risk.					.060	1.915
	Female x Moderate risk.						
	Male x High risk.					.999	1021204875.082
	Female x High risk.						
[a]Rows with redundant coefficients were removed. Coefficients in blank rows are set to zero because these are redundant. P-values in bold are significant on a $p < 0.05$ significance level.							

Table 7. Model 10 without random variables and mortality as target variable

Model 11			**F**	**df1**	**df2**	***p***	**Exp. Coefficent**
Model fit	Akaike Corrected IC	52.024					

	Accuracy	64.7 %					
Fixed effects	Corrected model		3.513	8	356	**.001**	
	Age groups		7.047	2	356	**.001**	
	Riskiness		.685	2	356	.505	
	Age groups x Risk.		.506	4	356	.731	
Fixed coefficients **(no-yes)**	Intercept					.424	2.000
	15-35					**.046**	.115
	36-65					.172	.275
	65+						
	Low risk.					.740	.743
	Moderate risk.					.815	.800
	High risk.						
	15-35 x Low risk.					.337	3.087
	15-35 x Moderate risk.					.676	1.693
	15-35 x High risk.						
	36-65 x Low risk.					.615	
	36-65 x Moderate risk.					.920 .899	
	36-65 x High risk.						
	a						

[a]Rows with redundant coefficients were removed.
Coefficients in blank rows are set to zero because these are redundant.
P-values in bold are significant on a $p < 0.05$ significance level.

Table 8. Model 11 without random variables and mortality as target variable

By including alcohol intoxication as a predictor for mortality, the best fitting GLMM was the one with the interaction between age group, sex, and alcohol intoxication (Model 26, Table 9). In the 15–35 age group, the survival chance of males after sTBI was about three times higher than that of females, if not intoxicated. Moreover, males in the 36–65 age group were five times more likely to survive if they were alcohol intoxicated on the day of the injury, compared to those who were not. The best model to predict mortality, however, was the one with only age group as a predictor variable (Model 31, Table 10), with exponential coefficients suggesting that the increase in age reduced the likelihood of survival.

Model 26			F	df1	df2	*p*	Exp. Coefficent
Model fit	Akaike Corrected IC	56.976					
	Accuracy	64.7 %					
Fixed effects	Corrected model		2.687	10	354	**.003**	
	Age groups x Sex x Alcohol int.		.320	10	354	**.003**	
Fixed coefficients (no-yes)	Intercept					.153	1.526
	15-35 x Male x Alcohol int.					.999	.000
	15-35 x Male x Not Alcohol int.					**.013**	.339
	15-35 x Female x Not Alcohol int.					.132	.262
	36-65 x Male x Alcohol int.					< **.001**	.208
	36-65 x Male x Not Alcohol int.					.070	.519
	36-65 x Female x Alcohol int.					.119	.164
	36-65 x Female x Not Alcohol int.					**.015**	.270
	65+ x Male x Alcohol int.					.908	.936
	65+ x Male x Not Alcohol int.					.918	1.042
	65+ x Female x Alcohol int.					.770	.655
	65+ x Female x Not Alcohol int.						
	a						
[a]Rows with redundant coefficients were removed. Coefficients in blank rows are set to zero because these are redundant. P-values in bold are significant on a $p < 0.05$ significance level.							

Table 9. Model 26 without random variables and mortality as target variable

Model 31			F	df1	df2	*p*	Exp. Coefficent
Model fit	Akaike Corrected IC	21.212					
	Accuracy	64.7 %					
Fixed effects	Corrected model		12.656	2	362	**<.001**	
	Age groups		12.656	2	362	**<.001**	
Fixed coefficients (no-yes)	Intercept					**.021**	1.531
	15-35					< **.001**	.241
	36-65					< **.001**	.358
	65+						
[a]Rows with redundant coefficients were removed. Coefficients in blank rows are set to zero because these are redundant. P-values in bold are significant on a $p < 0.05$ significance level.							

Table 10. Model 31 without random variables and mortality as target variable

3.4. Epidemiological-demografical analyses

To confirm the literature data, the incidence rates were analyzed by chi-square test using the statistical program SPSS 20.00. Results showed a significant difference in incidence rates between sexes along age groups ($\chi 2 = 31.652$; $P < 0.05$) (Table 11). Considering the frequency distribution, males aged 36 to 65 years were more likely to have suffered a severe traumatic brain injury and over 65 years for females, however, in consideration of the group aged 15 to 35 years, it was observed males were much more likely to have experienced a severe head injury than females during the same age period.

		Age groups				
		Under 15 y ears	15-35 years	36-65 years	Above 65 years	Total
Sex	male	5	**56**	**149**	74	284
	female	4	**7**	29	**50**	90
Total		9	63	178	124	374

Table 11. Sex ratio in relationship with age groups

A male predominance in alcohol consumption is also observed, i.e., males (N= 83) consumed alcohol at a much higher rate on the day of their injury than when compared with females (N= 7) ($\chi 2 = 17.204$; $P < 0.05$), i.e., men are more prone to alcohol consumption and consequently to suffer severe head injuries (Table 12). This relationship was also demonstrated using the Cramer association coefficient ($c = 0.214$; $P < 0.05$). A further related finding implies males were intoxicated on the day of the injury, which differed significantly among males in terms of the prevalence of alcohol history (alcohol abuse) (Table 13), and this was primarily in the group of males aged 36-65 years (Table 14).

		Day-of-injury alcohol intoxication		
		yes	no	Total
Sex	male	**83**	201	284
	female	7	83	90
Total		90	284	374

Table 12. Sex ratio in relationship with day-of-injury alcohol intoxication

Alcohol abuse			Day-of-injury alcohol intoxication		Total
			yes	no	
yes	Sex	male	**37**	14	51
	Total		**37**	14	51
no	Sex	male	46	187	233
		female	7	83	90
	Total		53	270	323
Total	Sex	male	83	201	284
		female	7	83	90
	Total		90	284	374

Table 13. Sex ratio, day-of-injury alcohol intoxication, alcohol abuse

Alcohol abuse			Day-of-injury alcohol intoxication		Total
			yes	no	
yes	Age groups	15-35 years	1	0	1
		36-65 years	**29**	12	41
		Above 65 év years	7	2	9
	Total		37	14	51
no	Age groups	Under 15 years	0	9	9
		15-35 years	11	51	62
		36-65 years	30	107	137
		Above 65 years	12	103	115
	Total		53	270	323
Total	Age groups	Under 15 years	0	9	9
		15-35 years	12	51	63
		36-65 years	59	119	178
		Above 65 years	19	105	124
	Total		90	284	374

Table 14. Age groups, day-of-injury alcohol intoxication, alcohol abuse

In terms of injury circumstances, motorcycle and motor vehicle accidents and falls (on pavement, ground and/or road) were the major contributors to severe head trauma in our sample. Furthermore, the descriptive data also show falls were the leading cause of severe TBI among individuals aged 36 to 65 years and 65 years and over, while motorcycle and motor vehicle accidents were the leading cause of severe TBI among individuals aged 15 to 35 years, which is significantly different from the frequency of other injury circumstances among these age groups ($\chi 2 = 153.7$; $P < 0.05$) (Table 15).

		Clustering of injury circumstances						
		motor vehicle/ road traffic accidents	falls	suicide	crashes, falls from height	violent activities	other reasons	Total
Age groups	Under 15 years	3	0	0	2	1	3	9
	15-35 years	**40**	6	0	3	4	10	63
	36-65 years	20	**89**	9	27	11	22	178
	Above 65 years	7	**83**	4	27	0	3	124
Total		70	178	13	59	16	38	374

Table 15. Distribution of injury circumstances according to age groups

4. Discussion

The willingness of young males to engage in dangerous situations might be adaptive in terms of fitness maximization. Nonetheless, for some individuals this intense sexual competition can be detrimental to health. The correspondence between the age distribution of the reproductively most active population and those suffering sTBI only partially supports the evolutionary hypothesis about risk-taking behavior. The prevalence of higher external mortality rates of young males, on the other hand, was not present in our data at all, nor did we find any support for the assumption that sTBI acquired from riskier behavior would lead to higher risk of death. In contrast, in our dataset on risky behavior and even alcohol intoxication, the results seem to coincide with lower mortality rates after the injury.

The term YMS refers to a specific demographic pattern of risktaking behavior. However, this phrasing has not been justified by our data, though our sample is not representative for the whole population, rather it consists of those who suffered serious brain injuries due to accidents.

Our results contrast with other studies suggesting that YMS may explain the risk taking behavior and mortality pattern among patients with sTBI. However, we propose that men might be more prepared to prevent at least some of the injuries. This might distort the proportions of males and females in the patient population from the patterns expected from evolutionary insights. Still, we wish to highlight that it would be important to convey novel data to re-analyze the correspondence between sex differences in risktaking behavior and mortality, and the YMS. The adherence to the conclusions in the original work of Wilson and Daly (1985) may result in a publication bias, wherein conflicting findings are less likely to be reported.

Contradictory results from epidemiological and demographic analyses have also been reported, which alerts us to the higher incidence of severe head injuries not only in the young (under 45 years) and older (over 65 years) age groups, but also in the middle-aged population, which is "saddled" with problems and burdens associated with the 21st century.

Future research on the relation between risk awareness, risk experience, and preparedness to danger may not only help to form new explanations about the demographic patterns in risk taking and its negative outcomes, but might also open up novel strategies in injury prevention and help reduce the incidence of TBI.

II. Comprehensive prospective examination of young, amatour male soccer players – previous results

Introduction

The majority of mild traumatic brain injuries often result from some form of sport and recreational activity, as confirmed by data acquired from the National Head Injury Association, and are mostly suffered by young males, in large part due to the increasing popularity of sports. In the United States, there are approximately 300,000 mild head injuries per year, defined as concussions in the majority of cases. Mild accidental brain injury or concussion is a closed head injury in which the brain collides with the base of the skull due to sudden force applied to the head, leading to deformity of brain tissue and/or blood vessels and functional problems. Minor brain injuries, as opposed to severe brain injuries, are less well known and often trivialized as a direct cause of long-term functional impairment, hence the term "silent epidemic".

Although mild traumatic brain injury is characterized by an easier and shorter recovery time than severe traumatic brain injury, it is now increasingly recognized even minor traumatic brain injuries such as those with specific symptoms, e.g., (dizziness, headache, irritability, anxiety, sleep disturbance, etc.) bear serious consequences in everyday functioning, especially if they are recurrent and their effects cumulative.

The incidence of concussions among young athletes is steadily increasing and is a growing public health problem on a global scale. There are also many unreported cases, as players are often unaware of the symptoms of the injury or underestimate the risks of suffering concussions. In contact sports, asymptomatic sub-concussive injuries (asymptomatic) often occur, which, when repeated, also increase neural vulnerability. Young athletes require recovery time due to their immature nervous system and should only return to the field following a suitable period of recovery.

Repetitive minor brain trauma, due to acceleration-deceleration forces, can produce complex structural, metabolic, neurochemical, neuroendocrine changes leading to increased deterioration and atrophy of axonal connections and neuronal cell membranes over the long term through several (stages I-IV), eventually resulting in irreversible brain deterioration and/or dementia. This phenomenon is known in scientific circles as 'chronic traumatic encephalopathy', 'dementia pugilistica' or 'punch-drunk syndrome' and is most associated with contact sports such as American football, lacrosse, ice hockey, wrestling or boxing. In American football, for example, up to 1400-1500 sub-concussive impacts upon athletes' brains occur during a season, in addition to symptomatic concussive injuries, and can be considered a significantly high number in terms of retraumatization and risk of degradation.

However, in repeated, mostly asymptomatic sub-concussive impacts, such as head impacts during football, there is still no consensus regarding brain, neurochemical and other changes and functional outcome.

1. Hypotheses

Our main objective was primarily to demonstrate the potential negative/harmful effects of long-term soccer, which according to published literature, are still controversial, and to identify personality factors which may indirectly contribute to players on-field behavior regarding the occurrence of minor head trauma and sub-concussive injuries.

- The neuro- and socio-cognitive performance among soccer players, due to many years immersed in the sport, lags behind that of a healthy control group, while not significantly different from the results of American football players.
- Literature suggests repeated mild head injuries can lead to long-term anxiety and mood disorders (depression). Accordingly, athletes (soccer players and American football players) perceive their health as worse and report more anxiety and depressive symptoms as a possible consequence of minor head trauma than healthy controls.
- Young male athletes are more impulsive, more extroverted and have fewer negative attitudes towards death than healthy controls. Furthermore, among soccer players, higher impulsivity, sensation seeking and extraversion (dynamism and dominance subscales) may be related to position on the field, attitudes toward death, as well as number of collisions, symptomatic concussions, and accordingly to self-reported complaints/symptoms.
- Structural brain MR images of soccer players show more significant micro lesions bearing clinical significance, using specific sequences, compared to healthy controls, however, they are not superior to American football players in this respect.
- Soccer players and american football players show elevated serum concentrations of some biomarkers (GFAP, UCH-L1, NF-L), which are of most predictive, diagnostic and somewhat prognostic value according to published literature, when compared to healthy controls.

2. Methods

The main goal of our current research was to compare the psychological, endocrine, biomarker and brain structural MRI results of young (18-40 years) male soccer players to the control group of healthy non-athletes or athletes with minimal risk of head injury (*control group 1*), as well as to the performance of athletes at higher risk for head injury (American football players) who may have higher rates of recurrent head traumas often associated with more severe concussion (*control group 2*). The groups were matched according to gender (male), age (18-40 years), and sample size (N = 6).

The level of education in all three groups is above 12 years on average (**$M_{soccer=}$ 14,3 years; $M_{american\ football}$= 17,1 years; $M_{healthy\ control=}$ 19,0 years**), therefore this factor did not influence the performance in the tests. Soccer players have been active for 17 years on average, and American football players for an average of 3 years.

Since the inception of the sport, footballers have suffered an average of **1.3** symptomatic concussions (number of them ranged from 0 to 5) and an average of **14** self-reported violent collisions/concussions. In consideration of US soccer players, since the onset of the sport, there has been an average of 0.5 symptomatic concussions (number of them ranged from 0 to 2) and an average of approximately **21.5** concussions/concussions with greater severity. Additionally, three of the soccer players are regularly on the pitch and in a striker position and three in a defensive position and have played an average of **28.16** games in the last year (position on the pitch and number of games played in less than one year were only interviewed and considered a target group).

An important criterion for selection was that soccer players and American football players should not have engaged in any other sport involving a high risk of head injury, as well as they should not have a history of a non-athletic, nor other - non-target - sport related skull or brain injury. In the case of the healthy control group, any prior brain trauma, as well as engaging in any sport involving high risk of head injury, was a ground for exclusion. The subjects were not currently suffering from any disease, or medical condition, they were vigil, and oriented (GCS = 15). Due to the low sample size (6 persons per group), our study is considered as preliminary, we would like to highlight the need for further studies with a larger sample size.

For soccer players (M = 26,8 years) and American football players (M = 27,5 years), psychological functions, biomarkers, and brain structure (MRI) were measured within two weeks of the end of the 5-month (spring) game season. From the point of view of the availability of the players, this proved to be the most ideal time. Members of the healthy control group (M = 30,0 years) were surveyed concurrently with soccer and American football players.

The whole study was performed in 2017 with the permission of the Regional Research Ethics Committee (file number: 6549) at Department of Neurosurgery of the University of Pécs. The data was processed anonymously in accordance with the obligation of confidentiality.

2.1. Imaging techniques

Possible structural brain abnormalities were detected by magnetic resonance imaging (Siemens MAGNETOM Prisma 3T MR) including scans made by T2, SWI (susceptibility-weighted imaging), FLAIR (fluid attenuation inversion recovery) and MPRAGE modalities. Finally, in reference to the healthy control group, two cases were not imaged, reducing the number of cases to four.

2.2. Proteine biomarker measurements

Among the protein biomarkers in head injuries, we focused first on the three markers shown to be effective in the acute diagnosis of injury (GFAP, UCH-L1) and in which we expected will detect the additive effect of recurrent mild head injury (NF-L). All three markers were detected from serum samples collected from athletes under laboratory conditions by a commonly referred to the sandwich ELISA method using commercially available ELISA kits (GFAP: Cat.No.:E-EL-H6093; UCH-L1: Cat.No.:E-EL-H2377; NF-L: Cat.No.:E-EL-H0741 - Elabscience, Wuhan, China). The measurements were performed on our BMG Labtech Clariostar (BMG Labtech Inc., Ortenberg, Germany) microplate reader in strict accordance to manufacturer's/technological recommended guidance.

2.3. Psychological examinations

The neuropsychological part of the study aimed to assess possible changes in cognitive functions, as these abilities are nearly indispensable for the performance of everyday activities and a normal lifestyle. During the psychological examination, we used a detailed and extensive test battery to thoroughly map the neurocognitive, socio-cognitive functions, emotionality, behaviour and certain personality factors of the subjects.

2.4. Statistics

Statistical analyses for psychological and imaging data were performed using the statistical software SPSS 22.00. For biomarkers, we used the statistical program R 4.1.1 (http://www.rproject.org/) in the RStudio 1.4.1717 environment (http://www.rstudio.com/). For comparisons between the results of the athletes and the healthy control group, we used t-tests, while in our more in-depth studies, which treated the biomarker values of each sport as separate groups, we used Holm's post hoc test for analysis of variance (ANOVA). All differences with $p \leq 0.05$ were considered

3. Results

3.1. Comparative assessments – soccer players, american football players, healthy controls

3.1.1. Imaging

Small non-specific white matter lesions of mostly no clinical significance were detected on imaging scans. For comparisons between study and control groups regarding the amount of possible lesions/changes, we used the Kruskall-Wallis test, justified by the low sample size.

3.1.1.1. T2 scans

No significant differences were found between groups (P>0.05; P=0.181), although when averages are considered, the proportion of non-specific white matter lesions was significantly higher among American football players (M=38.33) and soccer players (M=14.66) than when compared with the healthy control group (M=3.66) (Figure 1).

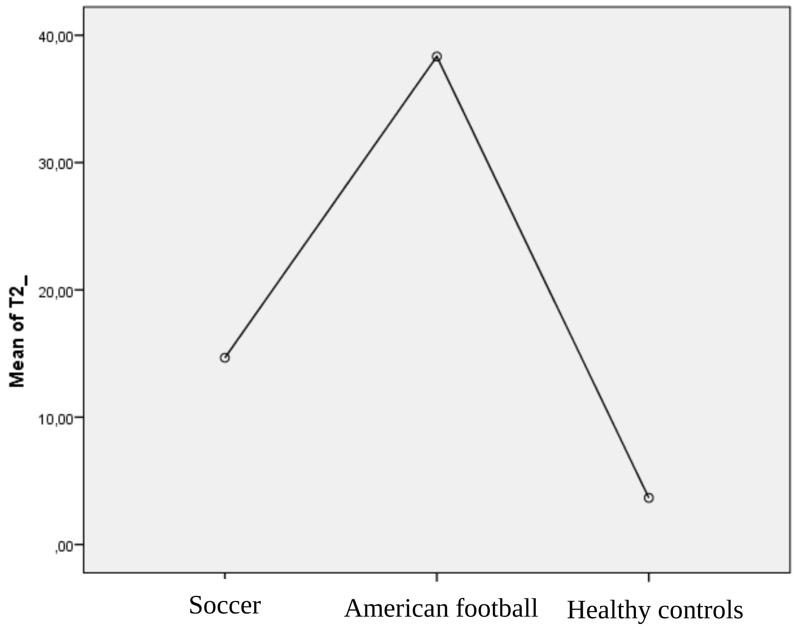

Figure 1. T2 – Mean of non-specific white matter lesions in groups

3.1.1.2. FLAIR

FLAIR recordings showed no difference in the number of lesions between the study and control groups (P>0.05; P=0.705), yet in terms of means, soccer players (M=1) and American footballers (M=0.83) outperformed the control group (M=0.16) (Figure 2).

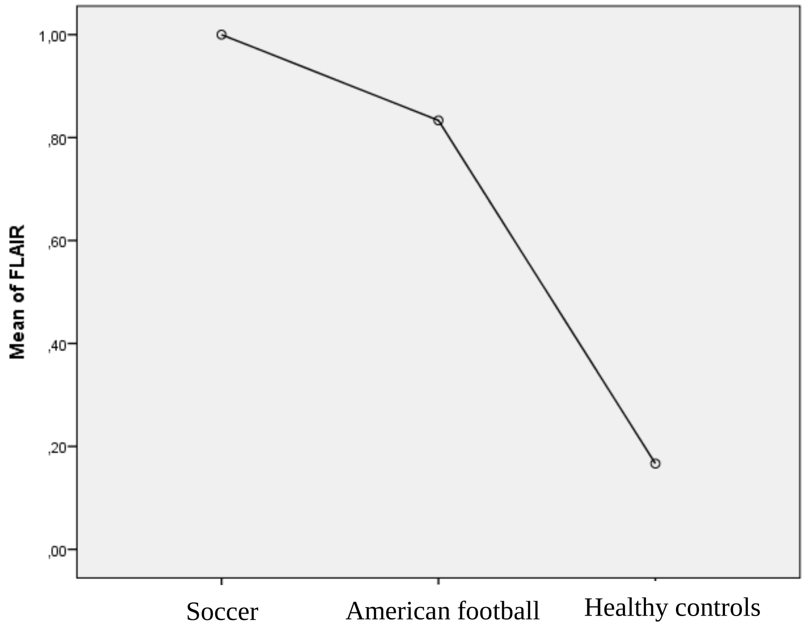

Figure 2. FLAIR – Mean of non-specific white matter lesions in groups

3.1.1.3. Susceptibility-weighted imaging (SWI)

In the SWI sequence-based recordings, we found no significant difference between groups in the number of non-specific lesions (P> 0.05; P= 0.120), and the means are not spectacularly different. Essentially, there was no such difference (lesion) at all for the American footballers, however, not for the other two groups (Figure 3).

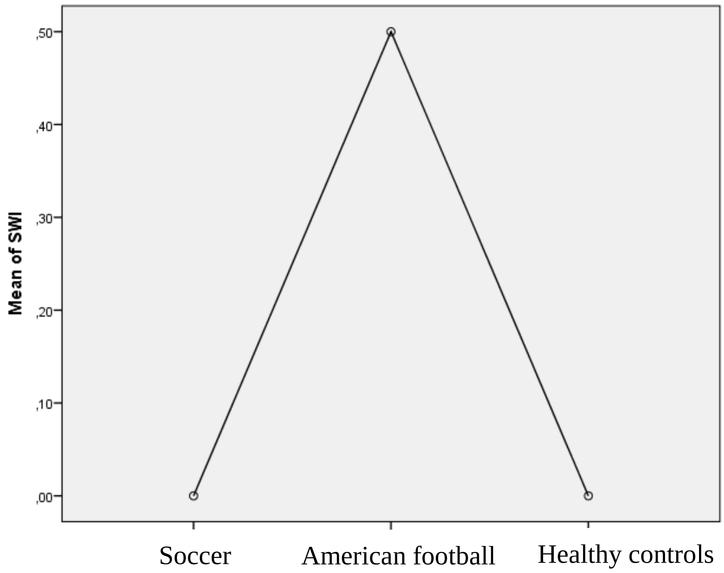

Figure 3. SWI – Mean of non-specific white matter lesions in groups

3.1.1.4. MPRAGE

No significant difference was observed between the test and control groups in the amount of non-specific lesions (P>0.05; P=0.344). However, the mean value was highest for soccer players (M=0.5), followed by American football players (M=0.33), with no such difference found in the healthy control group (M=0.00) (Figure 4).

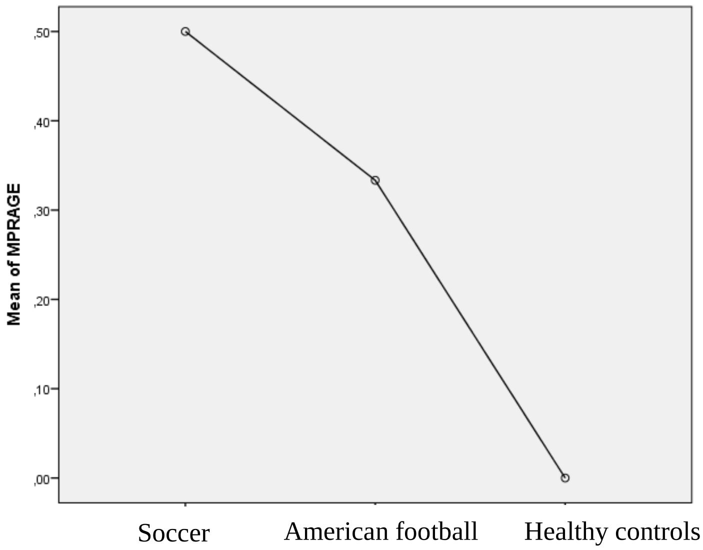

Figure 4. MPRAGE – Mean of non-specific white matter lesions in groups

3.1.2. Biomarker analyses

3.1.2.1. GFAP biomarker

In consideration of the GFAP biomarker, no significant difference was found between the study and control groups (P>0.05; P=0.297), however, on average, American football players had the highest percentage of GFAP biomarker detected in serum, followed by soccer players and finally the lowest in the healthy control group, only 27.36. Once the soccer players and American football players groups were pooled (athletes' group) and compared with healthy controls, a trend value was found (P>0.05; P=0.095). The results are illustrated in Figure 5.

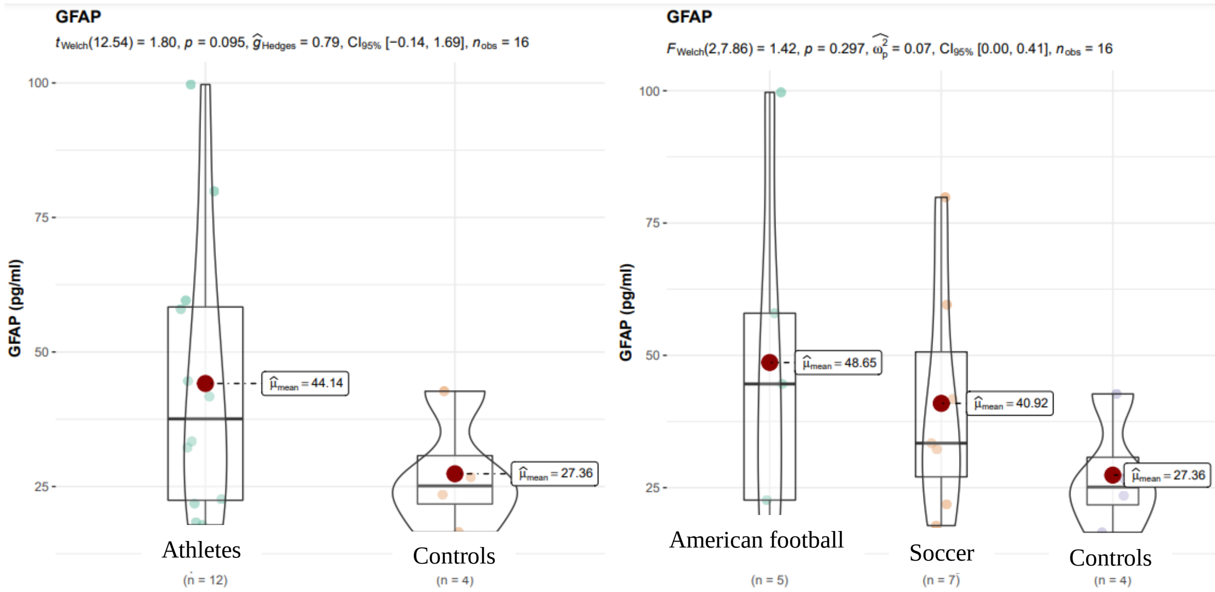

Figure 5. GFAP results

3.1.2.2. UCH – L1 biomarker

No significant difference was found between the study and control groups for the UCH - L1 biomarker (P>0.05; P=0.598), but on average, the American football players had the highest biomarker levels, followed by soccer players and finally the lowest levels in the healthy control group. When the groups of athletes were pooled (American football players and soccer players), no significant difference was found compared to the EC group (P>0.05; P=0.298), yet it was superior to the mean. The results are illustrated in Figure 6.

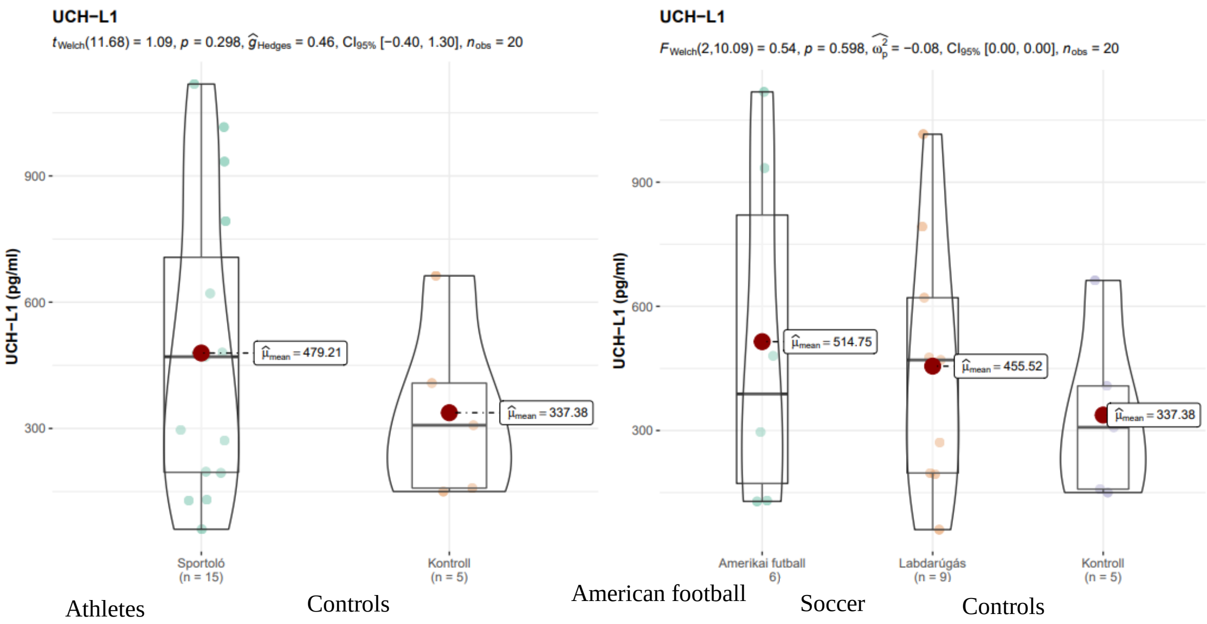

Figure 6. UCH-L1 results

3.1.2.3. NF-L biomarker

No significant difference was found between the groups (P> 0.05; P= 0.998), even when the athletes were pooled with the EC group (P> 0.05; P= 0.940). The mean values were nearly the same in both cases. The results are illustrated in Figure 7.

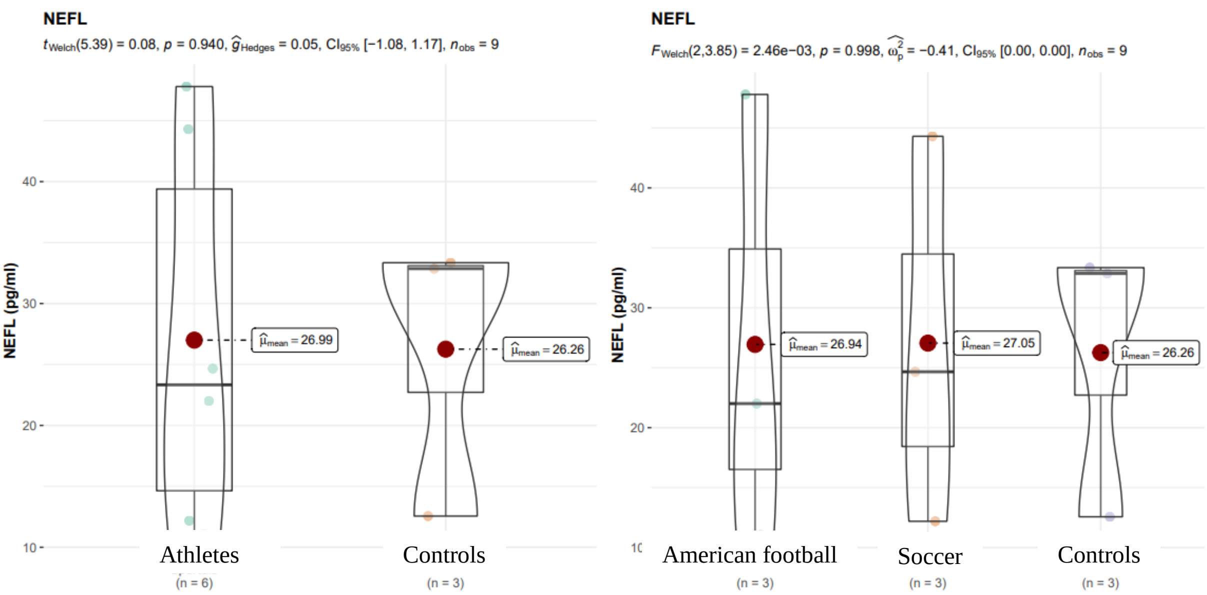

Figure 7. NF-L results

3.1.3. Psychology

3.1.3.1. Neuropsychology

Given the low number of items, analyses were performed using the non-parametric Kruskal-Wallis test. Significant difference was found only in TMT Part A (P <0,05; P = 0,003), showing that footballers (M = 18,21 sec) and American football players (M = 22,8 sec) had significantly faster psychomotor pace than healthy controls (M = 33,31 sec). In other neuropsychological tests significance was not revealed (P> 0,05). However, for RAVLT, in the first trial, in Part B, furthermore in the sixth and seventh trials, the control group performed best on average (but not significantly). In the Montreal Cognitive Assessment, which assesses the global cognitive capacity, the healthy control group also performed best, and the mild (1 point) difference, which is mainly revealed between the healthy control group and the soccer players, is attribute to results obtained in the verbal memory subtask (Table 1).

	Soccer players (M= mean)	**American football players (M= mean)**	**Healthy control group (M= mean)**
TMT A (sec)	18,2	22,8	33,3
RAVLT 1 (number of words)	7, 0	7, 0	8, 3
RAVLT 5 (number of words)	14,0	14,6	14,3
RAVLT B (number of words)	8, 5	8, 1	9, 3
RAVLT 6 (number of words)	12, 0	12, 3	13, 0
RAVLT 7 (number of words)	11, 5	11, 8	12, 5
MoCA (total score)	27,1	27,8	28,1
MoCA (verbal memory-immediate recall)	3,0	4,0	4,0

Table 1. Neuropsychological results I.

In Part B of the Trail Making Test, the healthy control group performed on average (but not significantly) poorer than the other two groups (soccer players and American football players), who performed at nearly the same level. In both subsections of the Verbal Fluency Test (phonological and semantic part) and Pattern Fluency (Five Point Test), the soccer players achieved the best results, however they did not differ significantly from those of the other two groups (Table 2).

	Soccer players (M= mean)	**American football players (M= mean)**	**Healthy control group (M= mean)**
TMTB (sec)	48,2	48,1	71,4
Verbal Fluency – phonemic (number of words)	48,1	41,1	39,8
Verbal Fluency – semantic (number of words)	67,1	53,5	59,5
Five-point test (number of correct patterns)	26,6	23,0	22,5

Table 2. Neuropsychological results II.

3.1.3.2. Social Cognition

In the Faux Pas test, all three groups answered the control questions equally well in the faux pas (FP) and control stories (CT), which means that the text was understood by the subjects. The healthy control group performed better on average in identifying/recognising and interpreting a faux pas, but the result did not differ significantly from that of the other groups. Surprisingly, however, athletes (soccer players, American football players) performed significantly worse than the members of the healthy control group ($P < 0,05$; $Pi = 0.012$, $P_v = 0,017$). On average, the healthy control group performed best in the comprehension of empathy, but in this case, the difference was not significant compared to the other two groups (Table 3).

	Soccer players (M= mean)	American football players (M= mean)	Healthy control group (M= mean)
FP_control (number of correct answers)	6,0	5,5	6,0
CT_control (number of correct answers)	6,0	6,0	6,0
FP_identification (number of correct answers)	10,6	9,6	11,3
FP_understanding (number of correct answers)	5,1	4,5	5,5
FP_intention (number of correct answers)	3,6	3,5	5,0
FP_belief (number of correct answers)	4,0	4,3	5,6
FP_empathy (number of correct answers)	5,1	5,0	5,8

Table 3. Results of social cognition

3.1.3.3. Psychodiagnostics

There was a significant difference between the groups (soccer players and members of the healthy control group) when tested with the Beck Depression Inventory, soccer players achieved the lowest score, while members of the healthy control group had the highest score (P <0,05; P = 0,005). There was also a significant difference in the NMMS test, soccer players got the highest scores, and American football players the lowest (P <0,05; P = 0,044). In relationship with the Beck Anxiety Inventory and the subscale of BFQ emotional control tendency values were showed between the groups (soccer players and subjects of the healthy control group) (P> 0,05; P = 0,06). Level of anxiety was the lowest for soccer players, the highest healthy controls, in case of emotional control, soccer players achieved the highest score and american football players the lowest (Table 4).

	Footballers (M= mean)	American footballers (M= mean)	Healthy control group (M= mean)
Beck Depression Inventory (score)	1,16	4,83	7,33
MFODS (score)	146,50	118,33	134,66
Beck Anxiety Inventory (score)	2,33	6,83	8,66
BFQ – emotional control (score)	44,50	32,33	37,16

Table 4. Psychodiagnostic results I.

The other psychodiagnostic tests did not show significant differences, however, the mean differences may be relevant for the interpretation of the results and for future studies. According to the SF-12 Health Survey, on average (but not significantly), soccer players are most satisfied with their health, followed by American football players and then by the healthy control subjects. According to RPQ, members of the healthy control groups report on more acute complaints on the average than the other two groups. Soccer and American football players scored higher, with nearly the same average, on the Barratt Impulsivity Scale (BIS) than the healthy control group. On the Zuckerman's 8-item Sensation Seeking Scale, soccer players had the highest scores, they were followed by American football players, then the subjects of the healthy control group, who are the less sensation seekers according to these results. On the dynamism subscale of the BFQ, american football players and soccer players have achieved more points (nearly the same) on the average, than healthy controls. On the dominance subscale, soccer players scored the highest, followed by american football players, and then finally by the members of the healthy control group who achieved the lowest score. On the impulse control subscale of the BFQ, the highest score can be observed in the case of soccer players and the lowest score was achieved by the American football players. According to the Lester Attitude Toward Death Scale, soccer players are the most positive towards death on the average, while members of the healthy control group are the most negative, and American football players are the most neutral. However, each group tends to have a more negative attitude toward death (Table 5).

	Soccer players (M= mean)	American football players (M= mean)	Healthy control group (M= mean)
SF-12 (score)	49,66	47,66	44,33
RPQ (score)	3,00	3,00	4,66
BIS (score)	68,33	68,16	60,16
BSSS_8 (score)	29,16	27,83	22,16
BFQ – dynamism (score)	41,00	42,00	37,00
BFQ – dominance (score)	41,00	38,33	35,66
BFQ – impulse control (score)	37,50	27,66	35,16
LATDS – positive (score)	13,45	12,65	11,85
LATDS – negative (score)	22,18	19,00	25,35
LATDS – neutral (score)	10,26	11,85	10,26

Table 5. Psychodiagnostic results II.

3.2. Correlations among soccer players – psychodiagnostics

The correlations between the variables were performed by Spearman's rank correlation analysis. The duration of playing soccer shows an inverse/negative correlation ($P \leq 0{,}05$; $P= 0{,}056$; $r= -{,}801$) with anxiety, which means that those who spend more time practicing soccer are less likely to experience anxiety. The number of matches played during the past (one) year is (negatively) related to the scores achieved in the SF-12 test ($P< 0{,}05$; $P= 0{,}036$; $r= -{,}841$), which means that those who have played more games over the past year rated their actual quality of life worse. The number of rough collisions and tackles suffered since beginning of soccer is also negatively correlated with the assessment of their current quality of life (SF-12) ($P\leq 0{,}05$; $P= 0{,}059$; $r= -{,}794$). The number of concussions and minor head injuries since the onset of playing soccer is significantly correlated with the number and degree of symptoms reported in the RPQ test (P< 0,05; P= 0,015; r= 0,898). An interesting finding is that the number of concussions (symptomatic mild head injuries), and the degree of symptoms reported in the RPQ test negatively correlate with the attitude toward death. Those who suffered more mild head injuries during their time playing soccer, were less positive (P< 0,05; P= 0,046; r= -,820) and neutral toward death (P< 0,05; P= 0,00; r= - ,984). Those who are currently reporting more symptoms about themselves (in RPQ), have also less positive attitudes toward death (P< 0,05; P= 0,022; r= - ,876). The number of rough collisions/impacts and tackles suffered since starting playing soccer is also significantly (inversely) related to the attitude toward death (P< 0,05; P= 0,005; r= - ,939), meaning that those who have suffered more of these collisions tend to be less neutral (mostly negative) toward death. The degree of sensation seeking is negatively and strongly correlated with the negative attitude toward death, which means that those who are more sensation seeker have a less negative attitude toward death (P< 0,05; P= 0,021; r= - ,880). During the years of actively playing soccer, the position filled on the field correlated positively with the scores obtained on the impulse control (P< 0,05; P= 0,021; r= ,878), emotional control (P< 0,05; P= 0,021; r= ,878), and dominance (P> 0,05; P= 0,06 /tendency value/; r= ,792) subscales of BFQ. Further finding is that anxiety levels are significantly linked to the degree of depressive symptoms (P< 0,05; P= 0,031; r= ,853) and the degree of impulsivity (P< 0,05; P= 0,021; r= ,880), according to which a higher level of anxiety is associated with a more depressive mood and, paradoxically, with a higher degree of impulsivity. Furthermore, the degree of impulsivity and sensation seeking is negatively correlated with age, which means someone is more younger, their behaviour is more impulsive (P< 0,05; P= 0,036; r= -,841) and sensation seeker (P≤ 0,05; P= 0,05; r= -,812). In addition, scores obtained on the dominance subscale of BFQ are positively correlated with the scores received on the impulse control (P< 0,05; P=, 0,036; r= ,841) and emotional control (P< 0,05; P= 0,008; r= ,928) subscales while are negatively correlated with the age (P≤ 0,05; P= 0,059; r= -,794). According to this latter result, those who are more confident are better at coping with their emotions and anxieties, and they are better at controlling their temper and dissatisfaction; moreover, younger people have a higher level of self-confidence.

4. Discussion

With this study, we aimed to explore the advantageous and disadvantageous of playing soccer among young males, and thus also to contribute slightly to the resolution of contradictions in this topic. One of the main limitations of our research was the low number of sample size, thus our results should be considered as awareness-raising and extensive conclusions could not be drawn from them. Notwithstanding, analyses suggest that long-term soccer playing has a positive effect on sport-specific neurocognitive abilities (e.g., making strategy, planning in time-limited tasks, psychomotor speed), which could be developed to a high level due to trainings and matches. Furthermore, playing soccer as a sport may have a positive beneficial effect on the mood, health, and psychological well-being, as well as could reduce anxiety and fear of death, and could increase the control of emotions and tempers despite the elevated levels of impulsivity. In addition to the positive effects, years of playing soccer may have negative consequences for cognitive and other psychological functions, some of which appear more to be obvious (e.g. low level of verbal memory and higher-order socio-cognitive abilities), while others (other cognitive, emotional factors) may be compensated by the beneficial effects, thus they are not considered as visible "threat."

Furthermore, repeated sub-concussive and concussive exposures during long-term soccer may result in elevated blood serum levels of certain biomarkers (GFAP, UCH-L1), indicating the negative impact of repetitive mild head trauma and the risk of subsequent more severe, symptomatic mild head injuries and brain tissue damage. Additionally, the number of non-specific white matter hyperintense lesions may also increase as a consequence of prolonged participation in this sport, the clinical significance of which remains to be clarified. Overall, however, the imaging, biomarker and psychological findings point in the same direction, suggesting even low-risk sports such as football may have long-term adverse effects and serious consequences. Furthermore, soccer players may be characterized as being more impulsive, sensation-seeking and dominant when compared with their non-athletic peers, and at least partial expression of this during the game may also contribute to reducing risk-taking tendencies" beyond the field," thus skirting involvement in accidents. Therefore, this type of sporting activity can be a direct internal preventive tool to reduce risk-taking tendencies to some extent (irrespective of gender), if, considering previous conclusions and replicating our results on a larger sample of elements, stricter guidelines are developed regarding the return to play, regulating the level of necessary sub-concussive influences (head impacts) (direct external preventive tools). The importance of (repetitive) mild head injury is increasingly recognized, and care systems are responding. In the United States, a network of Concussion Clinics is in place to screen out cases of complaints. Although the importance of follow-up is emphasized in current national care guidelines, unfortunately none of this is happening in practice. Our studies have also led to the establishment of a complex follow-up paradigm which serves as a model regarding the organization of systematic screening/referral tasks nationwide.

III. Summary of novel results

- In a large sample size (N= 374), we have partially detected the Young Male Syndrome (YMS) among patients with severe traumatic brain injury.
- Our results suggest risk-taking propensity and alcohol intoxication are associated with lower mortality rates following severe traumatic brain injury.
- Contrary to published literature, in our sample, the peak age at which severe head injuries occur is between 36 and 65 years, i.e., it is most often among the middle-aged population.
- We developed a multidisciplinary model for the follow-up and screening of patients with (recurrent) mild head injury.
- Playing soccer may be beneficial for psychological well-being and certain cognitive abilities in the long term (10-15 years).
- After a longer period (10-15 years), football may also have adverse health effects (neurochemical, psychological, neurological changes), although not yet significant.
- The results of the two studies suggest the introduction of the preventive model we have presented (1) indirect external, 2) direct external, 3) direct internal means) can contribute to the prevention of accidents and the negative consequences of mild and severe traumatic brain injuries.

IV. List of publications

List of publications based on the thesis:

Tamás, V., Kocsor, F., Gyuris, P., Kovács, N., Czeiter, E., Büki, A. (2019). The young male syndrome—An analysis of sex, age, risk taking and mortality in patients with severe traumatic brain injuries. Frontiers in neurology. 2019;10:366. (2019)

Tamás, V., Kovács, N., Büki, A. (2017). A sportolás és a baleseti agysérülés összefüggései: veszélyek és következmények. Ideggyógyászati szemle,70 (3-4). (2017)

Tamás, V., Büki, A., Herold, R. (2021). Mentalizációs deficit traumás agysérült betegek körében. Ideggyógyászati Szemle, 74(09-10), 295–307. (2021)

List of other publications:

Tamás, V., Sebestyén, G., Nagy, S. A., Horváth, P. Z., Mérei, Á., Tomaiuolo, F., ... & Büki, A. (2021). Provocation and prediction of visual peripersonal neglect-like symptoms in preoperative planning and during awake brain surgery. Acta Neurochirurgica, 1-7. (2021)

Raffa, G., Quattropani, M. C., Marzano, G., Curcio, A., Rizzo, V., Sebestyén, G., Tamás, V., Büki, A., & Germanò, A. (2021). Mapping and Preserving the Visuospatial Network by repetitive nTMS and DTI Tractography in Patients With Right Parietal Lobe Tumors. Frontiers in Oncology, *11*, 2106. (2021)

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Büki A, Tamás V, Kovács N. Sport és az agysérülés (tanjegyzet). „Sporttudományi képzés fejlesztése a dunántúlon 2015." című pályázat TÁMOP-4.1.2. E-15/1/KONV-2015-0003. Pécs, 2015. (2015)

Tamás V, Gyuris V, Kovács N, Czeiter E, Dóczi T, Büki A. Severe traumatic brain injury and the young male syndrome: psychological and evolutionary reasons behind etiology? Abstract. The 11th Symposium of The International Neurotrauma Society, Budapest, 2014-03-19. (2014)

Tamás V, Gyuris P, Kovács N, Czeiter E, Dóczi T, Büki A. Severe traumatic brain injury and the young male syndrome: Why do males take risks? Abstract. The 10th Alps Adria Psychology Conference, Lignano Sabbiadoro, Italy, 2012. (2012)

Conference abstracts – related to the present thesis:

Kocsor F, Tamás V, Kovács N, Czeiter E, Dóczi T, Büki A. Young Males with Injured Brains: a detrimental outcome of sexual competition**?** European Human Behaviour and Evolution Association Annual Conference. Paris, 2017. (2017)

Tamás V, Gyuris V, Kovács N, Czeiter E, Dóczi T, Büki A. Severe traumatic brain injury and the young male syndrome: psychological and evolutionary reasons behind etiology? The 11th Symposium of The International Neurotrauma Society, Budapest, 2014-03-19. (2014)

Tamás V, Gyuris V, Kovács N, Czeiter E, Dóczi T, Büki A. Súlyos koponyasérülés és a fiatal férfi szindróma összefüggése. Miért kockáztatnak a férfiak? XXXI. Országos Tudományos Diákköri Konferencia, Eger, 2013. (2013)

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Tamás V, Tasnádi E, Kovács N, Péley I, Büki A. Neuropszichológiai diagnosztika és rehabilitáció jóindulatú sella környéki térfoglaló folyamat esetén – esetbemutatás. Orvosi Rehabilitáció és Fizikális Medicina Magyarországi Társaságának XXXVII. Vándorgyűlése, Eger, 2018. (2018)

Tamás V, Németh M, Halasi I, Pallag A, Kovács N, Tasnádi E, Péley I, Büki A, Cserháti P. Korai cranioplastica hatása az akut neurorehabilitációs folyamat során – mi lehet az igazság? Orvosi Rehabilitáció és Fizikális Medicina Magyarországi Társaságának XXXV. Vándorgyűlése, Budapest, 2016. (2016)

Tóth A, Kovács N, Tamás V, Környei B, Nagy M, Horváth A, Bogner P, Janszky J, Dóczi T, Büki A, Schwarcz A. Microbleeds may progress acutely after traumatic brain injury. Neuroimaging Workshop, Szeged, 2015. (2015)

Tamás V, Gyuris P, Büki A. Súlyos koponyasérültek és koponyasérülést nem szenvedettek kognitív képességinek összehasonlítása a Trail Making teszt és a Verbális fluencia teszt alapján. Kari Tudományos Diákköri Konferencia, Pécs, 2011. (2011)

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