Neurological Sciences (2019) 40:1909–1915
https://doi.org/10.1007/s10072-019-03853-z

ORIGINAL ARTICLE

A semi-quantitative sport-specific assessment of recurrent traumatic brain injury: the TraQ questionnaire and its application in American football

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Received: 29 October 2018 / Accepted: 15 March 2019 / Published online: 19 May 2019

Abstract

Chronic traumatic encephalopathy (CTE) is very frequent and studied among contact sport players, above all American Football. Now, the defined diagnosis is only post-mortem and, consequently, more detailed diagnostic in-vivo instruments are needed to facilitate diagnosis and to allow a follow up. This clinical questionnaire (Trauma Questionnaire-TraQ) has been designed to investigate in parallel the traumatic load and clinical and cognitive subjective symptoms. It evaluates 4 anamnestic fields (specific sport activity, all previous pathological events, clinical manifestations compatible with TBI (traumatic brain injury) or CTE and subjective perception of personal memory efficacy with PRMQ questionnaire). The aim of TraQ questionnaire is to allow a standardized follow-up of active players and to identify subclinical disturbances that may become warnings. A pilot comparative study with TraQ on 105 subjects (75 AF players and 30 comparable people without a history of contact-sports activity) revealed that AF players have an increased amount of severe head trauma, an amplified level of subjective aggressiveness, more olfactory deficits but also more speech subjective problems, previously never related with CTE. In view of the obtained results, the TraQ seems to be useful (1) to obtain a better quantification of the traumatic load; (2) to differentiate the risk of long-term neurological consequences, allowing better management of different athletes right from the pre-symptomatic phases; (3) to manage prevention strategies if regularly applied to periodic visits to sports fitness; and (4) to identify the predisposing factors for the development of CTE and other neurological consequences of TBI with follow-up studies.

Keywords Traumatic brain injury · TBI · American football · Trauma questionnaire · TraQ · Chronic traumatic encephalopathy · CTE

Highlights
–The TraQ (Trauma Questionnaire) is manageable, detailed, and easily administrable.
–The TraQ confirms the importance of semiquantitative evaluation of TBIs (traumatic brain injury) for diagnoses, prevention, and follow-up
–Higher number of TBIs among athletes
–Athletes reported greater aggressiveness, olfactory problems, and problems of verbal expression

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10072-019-03853-z) contains supplementary material, which is available to authorized users.

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Background

For the diagnosis, monitoring and follow-up of acute TBI (traumatic brain injury) are available in specific flow charts, clinical scales, and guidelines (Teasdale Jennet 1974 [1]; De Giorgi Vitale 2002 [2]; McCrory et al. [3] SCAT2 British Journal of Sports Medicine 2009;43:i85–i88). However, the same abundance of material does not exist for recurrent chronic TBI. In contact sports such as rugby, American Football (AF), hockey, or boxing, recurrent mild TBIs are frequent and can have even very serious clinical consequences such as CTE (chronic traumatic encephalopathy) (Omalu DeKosky et al. 2005 [4]; Omalu DeKosky et al. 2006 [5]; Omalu 2008 [6]; Omalu et al. 2008 [7]; Blaylock Maroon 2011 [8]). As a result, it is necessary to keep these sports under observation (Omalu et al. 2005 [4]; Cambier et al. 2013 [9]).

Previous research often found conflicting results on the causal role sports played in the development of CTE, making it still an open question. The lack of a causal interpretation hinders a valid surveillance of such activities and prevents clinical, neuropsychological, and neuroimaging comparisons (Kim et al. 2009 [10]; Ge et al. 2009 [11]; Kinnunen et al. 2011 [12]; Hellyer et al. 2013 [13]; Liu et al. 2013 [14]; Pandit et al. 2013 [15]; Grossman et al. 2013 [16]).

A possible cause of the discrepancy in results from studies on TBI is the selection of comparison groups. Some studies, in fact, do not separate sportsmen from not athletes; others distinguish only "athletes" versus "not athletes," without taking into account other characteristics that can create large differences between different athletes, such as the type of sport and the field position.

To reduce these biases, it is necessary to consider the inter-individual variability of the sports history and the annual and total traumatic load of each athlete. Significant information are therefore the number of years of activity, the number of games and training sessions per year, the field position, the age, and other practiced sports. In contact sports—and in the specific case of AF—the dynamics of play, and consequently the characteristics of the traumatism, depends strictly on the quantitative and qualitative specifications of the sport activity.

Aim

The first objective of the study is the creation of an ad hoc questionnaire to establish in a semi-quantitative way the traumatic load of each athlete. We developed an easy-to-apply and repeatable tool that considers the field position, the amount of sports activity and the starting age of traumatic activity called the TraQ (Trauma Questionnaire). The first part of this questionnaire was designed specifically for American Football (AF) but can be adapted for each contact sport. The second part of the TraQ is applicable to every contact sport and evaluates the symptoms ascribable to chronic traumatic encephalopathy (CTE) and the prospective and retrospective memory through the PRMQ (Prospective and Retrospective Memory Questionnaire).

The secondary aim of the study was the application of the TraQ to a pilot population of AF players to evaluate its effective applicability in both a preliminary survey and for a comparative study.

Material and methods

The Trauma Questionnaire structure

Field position

- Offensive lineman, defensive lineman: predominantly quantitative TBI: high number of hits on the helmet—up to 5 per play and up to 300 in a single game—but on average each single hit is minimally intense. The "line" positions are those that most seem to correlate with the development of neurological sequelae (Omalu et al. 2005 [4]; Baugh et al. 2015 [17]).
- Quarter back, wide receiver, defensive back, special team (except kick returner): infrequent traumatism both in the game and in practice, but often at high intensity because it occurs in open field situations, with high speed or where the player cannot see the hitter before the impact (blind side hits). Few traumatic injuries overall, but often severe and concussive.
- Running back, tight end, linebacker, kick returner: frequent and potentially intense hits. The sports career of these athletes is shorter on average.

Amount of sport activity

– The most important determinant in the development of clinical consequences of mild traumatic brain injury (mTBI) is the repetition of traumas over time, rather than the intensity of a single trauma (Omalu et al. 2005 [4]). In order to consider this summing effect, it is necessary to know each athlete's total years of activity, the months of activity with contact per year, the number of full-contact practice per month and the number of games per year.
– There is a latency—often trauma-specific—between the TBIs and the pathology development (CTE) (Omalu et al. 2008 [7], Jordan 2013 [18], Victoroff 2013 [19], Montenigro et al. 2014 [20]). Due to this, it is crucial to know if the athlete is still playing or when he interrupted practicing AF.

TBI's beginning age

As some US studies on AF players in colleges—that started playing at a very young age—show, the shorter the time a person has practiced AF, the more likely that person is to develop neurological consequences (Farrey 2016 [21]), showing that the prevalence of pathological cognitive changes is greater for these athletes (Macciocchi et al. 2001 [22]). Given a similar age from the beginning of the exposure to the TBI, the effects are more harmful the shorter the time of inter-traumatic neuroplastic recovery (Bricolo et al. 2010 [23]).

CTE's clinical features

There are no specific diagnostic scores available for the precocious and preclinical phases of CTE. For this reason, the second part of the questionnaire investigates the presence of alterations and symptoms of CTE associated with repeated mTBI (mild traumatic brain injury) (Jordan 2013 [18]; Victoroff 2013 [19]; Montenigro et al. 2014 [20]), concussive head trauma, and post-concussion syndrome (Grossman et al. 2013 [16]) already perceived by the athlete. Examples include mood changes, aggressiveness, anxiety disorders, difficulty in attention and concentration, headache and related disorders (epiphenomena and aura), visual disturbances, sensory disturbances, olfactory and auditory disturbances, language difficulties, vertiginous sensations, nausea/vomiting, lipothimic events, palpitation, tremors, epistaxis, changes in the sleep/wake rhythm, movement disorders.

Prospective and retrospective memory evaluation

The TraQ is conducted by the administration of the PRMQ (Prospective and Retrospective Memory Questionnaire-Smith, Della Sala, Logye, Maylor, 2000 [24]) as TBI can cause memory problems both in acute phase, after a single TBI, and in long-term traumatism, in athletes with a history of TBIs, even mild but repeated over time. These problems can be transitory or even permanent in the short or medium term (Omalu DeKosky et al. 2005 [4], Cambier et al., 2013 [9]). The PRMQ allows the identification of athletes with probable pathological memory problems (with scores under the reference cutoff) that needs investigations with further diagnostic techniques. Above all, it allows the horizontal comparison between subjects, athletes, and patients with similar anamnestic or clinical characteristics, and the vertical comparison in the follow-up of the mnemonic performances of the same individual over time.

This questionnaire aims to investigate homogeneous groups of athletes in TBI studies in certain sports and it is designed for the research of specific markers and possible neuroradiological features of the neurodegenerative conditions induced by TBI.

The TraQ allows, in research studies of biological or neuroradiological markers, to correlate the findings of these investigations to the sporting anamnesis of the single athlete, that is to say the specific characteristics of his sporting TBI.

The TraQ questionnaire might be produced also in a multimedia version in order to allow a more comfortable and large-scale use and an easier data collection.

Population

Population of athletes by preliminary survey using TraQ:69 football players (AF), average age 25.2 ± 9.7 years, all males.

Population of athletes for comparative study: 29 athletes, all males; age range 17–48 years (maximum age limit for the American football practice in Italy established by FIDAF–Federazione Italiana Di American Football); at least 2 years of "tackle" American Football (AF) activity in FIDAF championships in the First Division, Second Division, or Under19 league; currently playing AF or retired for a maximum of 24 months; without previous concussive TBIs in other activities than AF (e.g., other contact sports, extreme sports, and car accidents) and with a negative history of serious diseases in progress, psychiatric or neurological disorders with sequelae.

Control population: 32 control subjects who have never played AF (not-AF)—comparable for age and sex.

We collected the following clinical information with the Trauma Questionnaire (TraQ):

1) Sport anamnesis (first 7 items): to define the total traumatic load of a subject from the quantitative (overall periods of exposure to TBI, first 6 points) and qualitative point of view (based on the roles and starting age) with particular reference to the practice of American Football

   - Age
   - Practiced sports and overall number of years of practice: to evaluate the possible cumulative effect of other sports where cranial trauma is possible (fight and contact sports, extreme sports and sports with vehicles).
   - AF starting year, year of stop and possible interruptions during the AF activity
   - Months of AF full-pads practice per year
   - Average number of full-pads practices per month
   - Average number of games per year
   - Field position (for groups of typical traumatism):

     (1) Offensive lineman, defensive lineman;
     (2) Quarter back, wide receiver, defensive back and special team (except kick returner);
     (3) Running back, tight end, linebacker, kick returner.

2) Remote pathological anamnesis:

   - Chronic illnesses, prior illnesses, hospital admissions, and interventions. Especially neurological and psychiatric disorders, alcohol and substance abuse, with and without cognitive impairment, which could alter performance in neuropsychological tests and neuroimaging.
   - Sports traumatic loss of consciousness, number of times: transient loss of consciousness (T-LOC) identifies a concussive TBI, it is one of the features that differentiates severe and minor TBI (Cambier et al. 2013 [9])
   - Non-sporting traumatic loss of consciousness, number of times
   - Epileptic seizures: the epileptic seizure has a double correlation with the cranial trauma. In fact, it can be both a cause of loss of consciousness with TBI after a fall to the ground, and a short-term consequence (early epileptic seizures), medium and long term (post-traumatic epilepsy) of the TBI (Cambier et al. 2013 [9]).

3) Symptomatic clinical history:

   - Reported mood: sad, happy, active, lazy, irritable
   - Aggressiveness perception at least partially unmotivated: no, sometimes, yes
   - Anxiety perception: no, yes a little, yes a lot
   - Subjective difficulty keeping attention or concentration during normal daily activities: never, sometimes, often
   - Headache: no, yes isolated episode, yes recurrent problem, from which age, related disorders (photophobia, phonophobia, osmophobia, nausea, allodynia, visual aura, paresthetic aura, aphasic aura)
   - Other transient disturbances during the day, not related to headaches: visual disturbances, paresthesia, anosmia, hyposmia, hyperosmia, hypacusia, tinnitus, transient aphasia, vertigo sensations, nausea / vomiting, fainting sensations, cardiopalmus, tremors, epistaxis, somnolence, loss of movement coordination, hypoesthesia, diplopia.

4) PRMQ (prospective and retrospective memory questionnaire-Smith, Della Sala, Logye, Maylor, 2000 [24]). It is a questionnaire consisting of 16 questions, 8 concerning prospective memory problems (PM) and 8 concerning retrospective memory problems (RM). Each answer attributes a score from 1 (very often occurring memory problem) to 5 (memory problem that never happens).The total score should be considered separately, from 8 to 40 points for prospective memory and from 8 to 40 points for retrospective memory; when pulled together the range (TM) is from 16 to 80 points. Although in the following years cutoffs have been proposed (PM = 16.5; RM = 18.5; TM = 31.5) - under which we may suspect a pathological memory problem - the greatest usefulness of this questionnaire is the horizontal comparison between subjects and patients with similar anamnestic and clinical features and vertical comparison in the follow-up of the mnemonic performance of the same individual over time.

Results

Demographic and clinical features

The Trauma Questionnaire (TraQ: see "Annex I - TraQ AF, pages 1-4 of 5" and "Annex II - TraQ AF, page 5 of 5") was given to 69 American Football (AF) players or former players, average age 25.2 ± 9.7 years, all males. The questionnaire showed that:

- 24 (34.78%) had at least one traumatic loss of consciousness, 15 for sporting reasons and 9 in a not sport=related situation;
- 46 (66.67%) report aggressiveness: 39 at minor levels and 7at greater levels;
- 8 (11.59%) report alterations in olfactory perception: 1 anosmic, 3 hyposmic, 4 hyperosmic;
- 16 (23.19%) report difficulties in verbal written / oral expression;
- 53 (76.81%) report attention / concentration difficulties: 37 mild and 16 significant;
- 54 (78.26%) report recurrent headache: 31 episodical and 23 chronic (more than 15 days per month)
- 17 (24.64%) experience recurrent paresthesias: 8 and 9 bilateral.

Since proportions were greater than what is available in the literature, we decided to make a comparison with a control group.

Among the 69 investigated athletes we selected those comparable for age and sex ($n = 29$) with a group of 32 not-AF subjects that served as a control, in order to make a comparison between similar groups.

Then we carried the comparative study using the TraQ on the 32 controls (not-AF) and 29 AF athletes - comparable for age and sex. The 29 athletes are all males; age range 17–48 years (maximum age to play American Football in Italy established by FIDAF–Federazione Italiana Di American Football); at least 2 years of "tackle" AF activity in FIDAF championships in the First Division, Second Division or Under19 League; currently playing AF or retired for a

maximum of 24 months; without previous concussive TBI in activities other than the practice of AF (e.g., other contact sports, extreme sports, traffic accidents, etc.) and with a negative history of serious diseases in progress, psychiatric or neurological diseases with sequelae.

The 29 athletes (AF) have average age of 25.8 ± 7.5 years; average schooling of 13.9 ± 2.6 years; they all report good health; previous interventions and diseases reported are mostly orthopedic, with the exception of two subjects who have a diagnosis of ADHD and one who had herpetic encephalitis in the childhood without any morphofunctional neurological consequence. None of the subjects has epilepsy or has ever had seizures.

Traumatic transient loss of consciousness

48.28% ($N = 14/29$) of the athletes reported having had at least one episode of traumatic transient loss of consciousness (TTLOC) during their lifetime: 10 during the activity sport and 4 unspecified. In the 32 controls (not-AF), subjects with at least one traumatic loss of consciousness are 18.75% ($N = 6/32$), only one of sports type ($\chi 2 = 18.876$, p value = 0.000014).

Aggressiveness

A subjective perception of at least partially unmotivated aggressiveness during the day is reported by 65.52% ($N = 17/29$) of the athletes and by 34.37% ($N = 11/32$) of the controls ($\chi 2 = 20.48$, p value = 0.000006).

Olfactory alterations

Olfactory alterations were found in 17.24% ($N = 5/29$) of AF subjects and 6.25% ($N = 2/32$) of controls ($\chi 2 = 5.945$, p value = 0.014763).

Subjective difficulties in verbal expression

31.03% ($N = 9/29$) of athletes report frequent transient episodes of verbal, written or oral difficulty. This disorder is reported by 3 of the 32 controls (9.37%) ($\chi 2 = 15.125$, p value = 0.0001).

Attention disorders, headache and paresthesias

Attention or concentration maintenance disorders during normal daily activities have been reported by 72.41% of AF players ($N = 21/29$) and 68.75% of controls ($N = 22/32$). No significant difference.

Headache is reported in 75.86% ($N = 14/29$): 8 are isolated episodes and 6 are configured as recurrent problem with an average frequency of 3 episodes per month, mean age of onset 17 years old and photophobia, phonophobia, nausea and aphasic aura are reported associated with the headache. 84.37% ($N = 27/32$) of the control group reported headache: 13 are isolated episodes and 14 are headache configured as a recurring problem. No significant difference.

24.14% of investigated AF players report predominantly bilateral paresthesia disorders versus 18.75% of the control group ($N = 6/32$: 3 unilateral and 3 bilateral), while only one AF player did not report any symptoms (3.45%), no one in the control group. No significant difference between groups.

The results of the Prospective and Retrospective Memory Questionnaire (PRMQ) referred to the subgroup considered are shown below and result in normal range in all subjects. These results will be especially used for a longitudinal prospective comparison and follow-up studies and allow us to compare AF athletes with not-AF controls.

1) Prospective Memory (PM): cutoff = 16.5/40 (AF subjects: average PM score = 28.9/40; range 21–34 to not-AF subjects: average PM score = 28.9/40; range 11–40);
2) Retrospective memory (RM): cut-off = 18.5 / 40 (AF subjects: average RM score = 32.8 / 40; range 23–38 - not-AF subjects: average RM score = 32.3 / 40; range 22–39);
3) Total Memory (TM): cut-off = 31.5 / 80 (AF subjects: average TM score = 61.7 / 80; range 44–72 - not-AF subjects: average TM score = 61.2 / 80; range 34–78).

No significant mean difference between the groups.

Discussion

As already mentioned in the introduction, it has long been clear the need for a questionnaire that can be used for sport related studies on TBI (Traumatic Brain Injury) and CTE (Chronic Traumatic Encephalopathy). In fact, to limit as much as possible the heterogeneity of the populations included in the current studies, it is key to standardize the qualitative assessment elements of the athletes under scrutiny. This heterogeneity interferes heavily on the results that are often, therefore, even conflicting. In its pilot application, the TraQ (Trauma Questionnaire) was manageable, detailed and easily administrable.

It would be desirable to develop a specific version of TraQ for every contact sport. This may be possible by adaptation of the first part of this questionnaire for each sport, as we made, in this pilot study, for American Football.

From conducting the TraQ anamnestic questionnaire to the pilot population emerged multiple and significant differences between American football (AF) players and controls (non-AF).

First of all, the higher number of brain injury among athletes proves that the practice of certain activities exposes them to a high risk of even intense head injury (Omalu et al. 2005

[4], Cambier et al. 2013 [9]): this suggest the usefulness of the traumatic load evaluation during periodic medical examinations and certification of fitness in certain sports.

Furthermore, some interesting data emerged. They concern a series of subjective disturbances potentially related to sports activity and possibly to the injury load estimated by the TraQ: the athletes of the pilot population reported a subjectively perceived greater aggressiveness compared to controls, apparently independent of the years of activity and from the role. A follow-up with TraQ would allow us to estimate if the subjective perception of aggression tends to turn into effective aggression, thus being considered as premorbid early phase of the typical CTE aggression ([7, 18–20]). Even the olfactory problems, notoriously associated with cranial traumatism, were statistically more frequent among athletes. This confirms that also in AF the TBI reduces or alters the olfactory sensitivity (Proskynitopoulos et al. 2016 [25]).

From the analysis of the results it is clear that AF players report even the subjective problems of verbal expression, written or oral, significantly more than for the controls. This data is not currently reported in the scientific literature.

As seen, none of these three parameters (subjective perception of being aggressive, dysosmia and subjective verbal problems), albeit more present in AF players, seems to correlate with years of activity and with the field position in a statistically significant manner. This suggests that the appearance of these disorders correlates with single significant traumatic events more than with the traumatic load.

The TraQ is therefore a possible tool to assign a quantitative-qualitative score that allows for a better clinical definition of the traumatic load in contact sports, a better management of athletes practicing these sports from the pre-symptomatic phases, and also for the management of prevention strategies, primary and secondary.

Conclusions

In view of the obtained results, the Trauma Questionnaire (TraQ) is useful to:

- obtain a better quantification of the actual and potential traumatic load in the athletes who practice contact sports (the first part customizable to each sport as a fact, in the pilot study, for American football);
- differentiate the risk of long-term neurological consequences in the different players, allowing better management of these athletes right from the pre-symptomatic phases;
- manage prevention strategies, primary and secondary, if regularly applied to periodic visits to sports fitness;
- identify the predisposing factors for the development of CTE and other neurological consequences of cranial traumatism in these athletes (e.g., age at the start of a sports career, dangerousness of the different field positions, predictable amount of TBI depending on field position, amount of hours of practice and number of games) with follow-up studies;
- compare the data obtained from the TraQ with the results of future functional neuroimaging and neuropsychological studies.

Acknowledgments Mr. Andrea Ibba provided language help.

Compliance with ethical standards

Conflict of interest statement The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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