

The journal has had 5 points in Ministry of Science and Higher Education parametric evaluation. § 8. 2) and § 12. 1. 2) 22.02.2019.

© The Authors 2021;

This article is published with open access at Licensee Open Journal Systems of Nicolaus Copernicus University in Torun, Poland

Open Access. This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author (s) and source are credited. This is an open access article licensed under the terms of the Creative Commons Attribution Non commercial license Share alike.

(<http://creativecommons.org/licenses/by-nc-sa/4.0/>) which permits unrestricted, non commercial use, distribution and reproduction in any medium, provided the work is properly cited.

The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 05.10.2021. Revised: 10.10.2021. Accepted: 26.10.2021.

## LONG-TERM CONSEQUENCES OF TRAUMATIC BRAIN INJURIES WITH ICE-HOCKEY PLAYERS

Volodymyr Sekretnyi, Oleh Nekhanevych

e-mail: [dr.sekretnyi@gmail.com](mailto:dr.sekretnyi@gmail.com)

Dnipro state medical university

Department of physical rehabilitation, sports medicine and valeology

V. Vernadskogo str., 9, Dnipro, 49044, Ukraine

### Abstract

#### Introduction

Contact sports (football, hockey, boxing, mixed martial arts, rugby and American football) are sports with high frequency of traumatic brain injuries (TBI). But a significant part of sports related concussions (SRC) are below the level of clinical diagnosis of SRC or are unnoticed. The most severe cumulative consequence of SRC is chronic traumatic encephalopathy (CTE). CTE is a progressive neurodegenerative disease accompanied by motor, psychological and cognitive disorders. Today, CTE widely resonates in the science world due to suicides among famous athletes. Despite the fact that this disease has been studied for almost 100 years, the diagnosis of CTE can be made only after autopsy. That is why the study of a wide range of clinical manifestations of CTE plays an important role.

#### Purpose

To establish long-term cognitive consequences of TBI in ice hockey players.

#### Material and methods

Retrospectively, we tested retired 20 ice hockey players (17 men and 3 women). All the players were winners of the Ukrainian Ice Hockey Championship and members of the national teams of Ukraine. The average age is  $34 \pm 9.4$  years, the youngest of them is 21 years old, the oldest is 51 years old. Also, players were divided into age groups: 18-28 years, 29-38 years, 39

and older. All athletes had at least one SRC (7 athletes had 1 SRC, 2 SRC – 3 athletes, 3 SRC – 6 athletes, 4 and more – 4 athletes). 7 hockey players were hospitalized after having had SRC (which indicates the severity of SRC). All athletes completed a questionnaire with their team doctor, which included: passport part, sports history, history of SRC, a mini mental scale evaluation (MMSE) and «the clock drawing test».

## **Results**

Dividing athletes into groups according to the number of SRC received during their professional career, we compared their MMSE result. The results of the analysis showed a statistically significant decrease in the value of MMSE with an increase in SRC more than 1 during a sports career. Thus, in the group with 1 SRC the value of MMSE was 28.7 (1.38) points, while in the group with 2 or more SMS it was equal to 26.7 (1.15) points ( $p < 0.05$ ). While analyzing the level of MMCE, depending on the sports specialization in hockey, statistically significant differences were found. Therefore, MMSE goalkeepers scored 26.6 (0.6) points, strikers – 27.8 (0.4) points, defenders – 28.2 (0.7) points ( $p < 0.05$ ). In addition, the fact of hospitalization indicates clinically significant severity of a history of SRC. Having retrospectively collected data on hospitalization of hockey players after SRC, there was also a decrease in the value of MMSE in those with a history of hospitalization. Thus, in the group of people with hospitalization MMSE was 27.1 (1.39) points, without hospitalization – 27.9 (1.7). An analysis of the relationship between age groups and the nature of cognitive impairment has also been made. No statistically significant data was found, indicating no relationship between age and severity of cognitive impairment. Significant statistic connection ( $n = 20$ , correlation coefficient  $r_s = -0.40$ ;  $p < 0.05$ ) has been found between the number of SRC and the indicator and MMSE test and between number of SRC and «the clock drawing test» ( $n = 20$ , correlation coefficient  $r_s = -0.10$ ;  $p < 0.05$ ). These data suggests that the amount of SRC affects cognitive functions.

## **Conclusions**

Our study has outlined connection between cognitive impairment in ice-hockey players and SRC. Despite the fact that the world literature emphasizes the importance of cognitive testing both to guide athletes before and after SRC, and to assess the long-term effects of SC, there is no one diagnostic protocol and it requires unification and mandatory inclusion in the diagnostic program for the athlete who had SRC.

**Key words: ice hockey, sports related concussion, chronic traumatic encephalopathy, cognitive impairment.**

## Introduction

Most sports games and martial arts are contact kinds of sports and are the most attractive to spectators, sponsors and the media. But such kinds of sports as football, hockey, boxing, mixed martial arts, rugby and American football are associated with high risk of traumatic head injury (TBI) [1].

According to the 5th International Conference on Concussions in Sports (October 27-28, 2016, Berlin), the definition of sports related concussion (SRC) is a brain injury, which can be caused by a direct blow to the head or others parts of the body that can be transmitted to the head, what usually leads to rapid and short-term neurological dysfunction, which gradually regresses, but can sometimes be long-lasting and persistent. SRC can also lead to neuropathological changes, mainly functional, which can not be visualized by neuroimaging and can occur with or without loss of consciousness [2]. According to this definition, the logical conclusion would be that a large number of athletes (especially in contact sports) can get TBI during their sports careers, which are below the threshold of clinical diagnosis of concussion [3]. Such TBI can be unnoticed by athletes, their coaches and team doctors for a variety of reasons, the main of them is the achievement in sports results by any means and the difficulty in diagnostics of clinical signs of the injury [1]. Mez J. and oth. made the definition of "pre-concussion" as the transfer of mechanical energy to brain with sufficient force to damage the integrity of axons or neurons, but not being expressed in clinical symptoms [4]. Despite the fact that today there is a clear understanding of the potential mechanisms of SRC, the mechanisms of delayed consequences of TBI are completely unclear [5].

In 1928 pathologist Harrison Martland was the first to describe the clinical syndrome of progressive neurological deterioration in boxers, which was called "dementia puglistica." Boxers with repeated head injuries had following complications: confusion, slow movement, tremor, problems with speaking etc. The term chronic traumatic encephalopathy (CTE) was first used by neurologist MacDonald Critchie in 1949. And in 1973 Corsellis et al described a pathoanatomical picture of CTE in 15 former boxers. The main signs of CTE were reduced brain mass, dilation of the lateral and third ventricles, sinus in septal cavity with fenestration, thinning of the hypothalamic floor, atrophy of the vault and mammary body, thinning of the corpus callosum, depigmentation of the substantia nigra, scarring of the tonsils of cerebellum. The real resonance in sports science began after the publication of the work of neurologist Omalu in 2005 and 2006, in which he described two cases of suicide in American football players due to the development of CTE, confirmed by autopsy [6]. Recent studies show a link between TBI and neurodegenerative conditions [7,8]. CTE is a progressive neurodegenerative condition caused by a single or repeated TBI and covers the clinical spectrum

of motor, psychological and cognitive symptoms [9]. This complex of symptoms can persist throughout the life of athletes [10]. According to the consensus of the National Institute of Neurological Disorders and Stroke and the National Institute of Biomedical Imaging and Bioengineering, the final diagnosis of CTE can only be made at autopsy (USA, 2015). In addition, criteria for the diagnosis of CTE have been proposed: perivascular accumulation of abnormal tau in neurons and astroglia distributed perivascularly at the depths of the apex of the isocortex in the form of an irregular pattern [11]. The proof that repeated neurotrauma is a risk factor for suicide among former athletes has been confirmed by other authors [12-14]. What is more, data on neurodegenerative symptoms not only among elite athletes, but also among young athletes who had SRC, negatively affects the decision of parents to introduce sports to their children [15]. That is why the diagnosis of the cumulative effects of SRS is extremely necessary.

According to the International Ice Hockey Federation (IIHF), which studied injury statistics during the World Championships and the Olympic Games among men's national teams (players of adult men's team and teams under 20 and 18 years old) and women's teams (players of adult team and national teams under 20 and 18 years old), 10% of all injuries were SRC - 160 cases per 3293 games [16]. According to Renton T et al, 22% of Canadian hockey players (n = 5223 athletes) at the age of 10-25 years old, were diagnosed with 1 or more SRC [17]. Many studies show that SRC can cause disturbances in various cognitive areas, including the ability to learn, memory, information processing speed, attention, etc. [18]. Even a mild form of SRC is the leading cause of both short-term and long-term cognitive impairment for hockey players [19]. Back in the 1980s athletes began to perform neurocognitive testing, comparing post getting SRC and pre-season testing data in order to assess the recovery of the athlete [20]. Currently neurocognitive tests are used in approximately 30% of universities and 40% of sports medicine universities [21, 22]. Cognitive testing in the acute period can also be helpful for identifying athletes who are at risk of slower recovery than expected as well as detecting cognitive impairment among athletes without complaints [23, 24]. In particular, Broglio et al. have found that approximately 38% of athletes after getting SRC continued to show deficiency in at least one neurocognitive function, such as verbal memory, visual memory, visual-motor speed or reaction time [25]. The National Hockey League (NHL) uses a hybrid approach that consists of "paper and pencil" (P&P) testing and computerized measures, mainly the IMPACT test (immediate post-concussion assessment and cognitive testing) [26]. The IMPACT test is widely used as computerized screening of cognitive changes associated with SRC in Finland [27]. The ImPACT test was also performed to assess recovery among NHL players during 2 to 4 year time intervals based on post SRC testing. As a result, the two-factor speed index has shown improvement in players' memory, which indicates the ability of the test to detect cognitive

changes after injury and increases its diagnostic usefulness. Scientists have concluded that cognitive testing allows better recovery, reducing the risk of getting another injury by the athlete, when the GM may be more vulnerable to re-injuring [28]. Assessment of 102 athletes from the 2012-2014 NHL Draft (51 with a previous diagnosis of concussion and 51 athletes from the control group). Participants performed two computer tasks based on cognitive-motor integration. Participants from “the concussion group” showed significantly slower response times during the task and higher number of errors compared to “the control group”[29]. Experienced athletes "veterans" of the NHL (N = 33, aged 34-71 years) and the control group (N = 18), who complied with all the requirements for exclusion of criteria for the signs of neurological pathology and severe dementia (neurological examination, magnetic-resonance imaging, electroencephalography, blood for genotyping and lumbar puncture for analysis of cerebrospinal fluid proteins associated with dementia, etc.) underwent a package of standardized neuropsychological tests and computerized cognitive tests. The neuropsychological test assessed intellectual functioning, attention, memory, visual-spatial orientation, and executive functions. Computerized tests included CogState29 tests and selected tests from Cambridge Brain Sciences (CBS). Confirmed group differences in cognitive activity were observed at tests of executive and intellectual functions; which were associated with the effects of concussion. Group differences were observed in cognitive, affective, and behavioral disorders in psychosocial questionnaires. Scientists have concluded that “veteran” athletes had objective cognitive impairment in cases of actual complaints [30]. Therefore, cognitive testing is extremely important for cumulative assessment of the consequences of SRC for athletes who have finished their career, and for monitoring active athletes, assessing their recovery after SRC and observing them during their training and competition activities.

### **Purpose**

To establish long-term cognitive effects of TBI among ice hockey players.

### **Material and methods**

Retrospectively, we have conducted testing of 20 ice hockey players (17 men and 3 women) who had finished their sports careers. All of the players were winners of the Ukrainian Ice Hockey Championship and members of the national teams of Ukraine. The average age of the hockey players was  $34 \pm 9.4$  years, the youngest of them was 21 years old, and the oldest was 51 years old. Also, the ice hockey players were divided into age groups: 18-28 years old, 29-38 years old, and 39 and older. All athletes had at least one diagnosed SRC (7 athletes had 1 SRC, 2 SRC - 3 athletes, 3 SRC - 6 athletes, 4 and more SRC - 4 athletes). 7 hockey players were hospitalized after getting SRC (which indicates the severity of the SRC). During training and competitive activities all athletes were examined every year in sports medicine clinics: athletes

did not have concomitant neurological pathology and they stopped competitive training activity not due to neurological abnormalities. All athletes who were included in the study did not have in their anamnesis any other causes of concussion other than playing hockey.

All athletes filled in a questionnaire in the presence of a team doctor, which included: passport part, sports history, SRC history, short scale of psychological status of Mini-mental State Examination (MMSE) and the "drawing a clock" test. To date, MMSE is one of the most commonly used scale in assessing cognitive impairment [31]. The patient is asked to consistently answer 10 questions that assess time and place orientation, attention, perception, concentration, memory and speech [32]. The total result for the test is calculated by summing up the results for each of the items. A maximum of 30 points can be scored in this test, which corresponds to high cognitive abilities. The lower the test result, the more significant are changes in memory and intellectual impairments. A score of 29-25 points corresponds to mild or moderate cognitive impairment. A score of 24 or lower indicates that the patient has severe cognitive impairment. The "clock drawing" test has proven effectiveness in the diagnosis of cognitive disorders [33]. The patient is asked to draw a clock with numbers on the face on a sheet of paper, and the clock hands show the time 1.45. There are many methods for evaluating test results. We used a 10-point (10-maximum score) Rulo technique, which evaluates the three components of the figure: the integrity of the clock circle (2 points), the presence and sequence of numbers (4 points), the presence and placement of clock hands (4 points), giving a total of 10 points, with higher figures indicating better performance [34].

Statistical analysis of the results was performed using the licensed software program STATISTICA (6.1, serial number AGAR909E415822FA). Checking normality was performed by Shapiro-Wilk W-test. Significance of differences between indexes was performed taking into account the type of distribution using Student's t-test, Mann-Whitney U-test and Pearson's chi-square test. ANOVA / MANOVA analysis of variance was used to determine the effect of the study factors on the study groups. Pearson's r-test was used to study the correlation level. The threshold level of statistical significance of the obtained results was stated at  $p < 0,05$ . The results are presented as M (SD) for quantitative indicators and as a percentage for qualitative indicators.

The research was conducted in accordance with the principles of the Helsinki Declaration of the World Medical Association "Ethical principles of medical research concerning human subjects" (amended in October 2013). Permission to conduct research was obtained by the Ethics Committee of the Dnipro state medical university. Written informed consent was obtained from all patients who participated in this study.

## Results

2 athletes (10%) showed a maximum score of 30 on the MMSE test, the remaining 18 athletes (90%) had a score in the range of 26-29, indicating the presence of cognitive impairment of mild and moderate degree. All the athletes made mistakes in questions that characterized attention and (or) memory. 4 (20%) hockey players showed a maximum score of 10 points in the test "drawing the clock", the rest (80%) with a score of 9 points, which also indicates mild cognitive impairment.

The main interest of study is the cumulative effect of TBI during players' careers. After dividing athletes into groups according to the number of SRC received during a professional career, the rates of MMSE tests were compared. The results of the analysis have shown a statistically significant decrease in the rate of MMSE with an increase in SRC for more than 1 during a sports career. Thus, in the group with 1 SRC the rate of MMSE was 28.7 (1.38) points, while in the group with 2 or more SMS it was equal to 26.7 (1.15) points ( $p < 0.05$ ).

The average scores on the tests performed, depending on the number of SMS received during the career are shown in Table 1.

**Table 1.** Average results of the MMSE test and the "Drawing the clock" test, depending on the number of SRC received by hockey players during their career.

Number of SRC	Number of athletes	Sports specialization			Average result of MMSE test, M (SD)	Average result of "drawing a clock" test, M (SD)
		Goalkeepers	Defenders	Forwards		
1 SRC	7	1	2	4	28,7 (1,4)*	9,5 (0,5)
2 SRC	3		1	2	26,7 (1,2)	9 (0,1)
3 SRC	6	1	1	4	27,7 (1,6)	8,8 (0,9)
4 SRC and more	4	1	1	2	26,7 (1,5)	9 (0)

Note \* -  $p < 0.05$ .

While analyzing the level of MMSE depending on the sports specialization in ice-hockey, statistically significant differences have been found. Thus, goalkeepers completed 26.6 (1.15) points in MMSE test, forwards - 27.8 (1.53) points, defenders - 28.2 (1.83) points ( $p < 0.05$ ).

In addition, the fact of hospitalization indicates a clinically significant severity of a history of SRC. Retrospectively collecting data of the hospitalization of ice-hockey players after SMS, there was also a decrease in the rate of MMSE level in those with a SRC in anamnesis. Thus, in the group of people with hospitalization score of MMSE was 27.4 (1.39) points, without hospitalization - 27.9 (1.7) points.

The relationship between age groups and types of cognitive impairment has also been analyzed. No statistically significant data has been found, indicating that there is no relationship between age and severity of cognitive impairment.

There was a statistically significant, medium-strength correlation ( $n = 20$ , correlation coefficient  $r_s = -0.40$ ;  $p < 0.05$ ) between the indicators of the number of SRC and the result of MMSE test, which indicates that the greater the number of SRC, the more represented cognitive impairment.

## **Discussion**

The prospect of further research is the development and scientific substantiation of the professional ice-hockey players after SRC management protocol.

## **Conclusions**

1. Our study has shown a link between cognitive impairment in ice-hockey players and SRC, namely the influence of the number and severity of SRC received by athletes.

2. Despite the fact that the world literature emphasizes the importance of cognitive testing both to guide athletes before and after SRC, and to assess the long-term effects of SRC, there is no common diagnostic algorithm and it requires unification and mandatory inclusion in the diagnostic program of the athlete with a history of SRC.

## **References**

1. Gallo V, Motley K, Kemp SPT, Mian S, Patel T, James L et al. Concussion and long-term cognitive impairment among professional or elite sport-persons: a systematic review. *J Neurol Neurosurg Psychiatry*. 2020;91(5):455-468.
2. McCrory P, Meeuwisse W, Dvořák J, Aubry M, Bailes J, Broglio S, et al. Consensus statement on concussion in sport—the 5<sup>th</sup> international conference on concussion in sport held in Berlin, October 2016. *Br J Sports Med*. 2017;51:838–47.
3. Gardner AJ, Howell DR, Levi CR, Iverson GL. Evidence of concussion signs in national rugby League match play: a video review and validation study. *Sports Med – Open*. 2017;3:29.
4. Mez J, Daneshvar DH, Kiernan PT, Abdolmohammadi B, Alvarez VE, Huber BR et al. Clinicopathological evaluation of chronic traumatic encephalopathy in players of American football. *JAMA* 2017;318:360–70.
5. Carson A. Concussion, dementia and CTE: are we getting it very wrong? *J Neurol Neurosurg Psychiatry*. 2017;88:462-4.
6. Mckee AC, Abdolmohammadi B, Stein TD. The neuropathology of chronic traumatic encephalopathy. *Handb Clin Neurol*. 2018;158:297-307.



7. Gardner RC, Yaffe K. Epidemiology of mild traumatic brain injury and neurodegenerative disease. *Mol Cell Neurosci.* 2015;66:75–80.
8. Pearce N, Gallo V, McElvenny D. Head trauma in sport and neurodegenerative disease: an introduction and review of the epidemiological evidence. *Occup Environ Med.* 2017;74.
9. Tartaglia MC , Hazrati L-N , Davis KD , Green RE, Wennberg R, Mikulis D et al. Chronic traumatic encephalopathy and other neurodegenerative proteinopathies. *Front Hum Neurosci.* 2014;8:30.
10. Covassin T, Elbin R, Kontos A, Larson E. Investigating baseline neurocognitive performance between male and female athletes with a history of multiple concussion. *J Neurol Neurosurg Psychiatry.* 2010;81:597–601
11. McKee AC, Cairns NJ, Dickson DW, Folkerth RD, Keene CD, Litvan I et al. The first NINDS/NIBIB consensus meeting to define neuropathological criteria for the diagnosis of chronic traumatic encephalopathy. *Acta Neuropathol.* 2016;131 1:75– 86.
12. Fralick M, Thiruchelvam D, Homer C, Tien C, Redelmeier D. Risk of suicide after a concussion. *CMAJ.* 2016;1887:497-504.
13. Hal S. Wortzel, Robert D. Shura, and Lisa A. Brenner . Chronic Traumatic Encephalopathy and Suicide: A Systematic Review. *Biomed Res Int.* 2013;42:42-80.
14. Goldstein L, Diaz-Arrastia R. Traumatic Brain Injury and Risk of Suicide. *JAMA.* 2018;320(6):554-556.
15. Di Virgilio TG, Hunter A, Wilson L, Stewart W, Goodall S, Howatson G et al. Evidence for acute electrophysiological and cognitive changes following routine soccer heading. *EBioMedicine.* 2016.13:66-71.
16. Tuominen M, Hänninen T, Parkkari J, Michael JS, Luoto T, Kannus P et al. Concussion in the international ice hockey World Championships and Olympic Winter Games between 2006 and 2015. *BJSM.* 2016:244-252.
17. Renton T, Howitt S, Marshall C. Lifetime prevalence of concussion among Canadian ice hockey players aged 10 to 25 years old, 2014 to 2017. *J Can Chiropr Assoc.* 2019;63(2):80-91.
18. Howell DR, Osternig L, van Donkelaar P, Mayr U, Chou L-S. Effects of concussion on attention and executive function in adolescents. *Med. Sci. Sports Exerc.* 2013;45(6):1030-1037.
19. Emery CA, Kang J, Shrier I, Goulet C, Hagel BE, Benson BW et al. Risk of injury associated with body checking among youth ice hockey players. *JAMA.* 2010;303:2265-2272
20. Barth JT, Alves WM, Ryan TV, Macciocchi SN, Rimel RW, Jane, JA et al. Mild Head Injury in Sports: Neuropsychological Sequelae and Recovery of Function. Levin HS, Eisenberg HM, Benton AL, editors. Oxford University Pres. 1989, 257-275.

21. Meehan WP, d'Hemecourt P, Collins CL, Taylor AM, Comstock RD. Computerized neurocognitive testing for the management of sport-related concussions. *Pediatrics*. 2012;129(1):38-44.
22. Baugh CM, Kroshus E, Stamm JM, Daneshvar DH, Pepin MJ, Meehan WP. Clinical practices in collegiate concussion management. *Am. J. Sports Med*. 2016;44(6):1391-1399.
23. Moser RS, Iverson GL, Echemendia RJ, Lovell MR, Schatz P, Webbe FM et al. Neuropsychological evaluation in the diagnosis and management of sports-related concussion. *Arch. Clin. Neuropsychol*. 2007;22(8):909–916.
24. Iverson G. Predicting slow recovery from sport-related concussion: the new simple-complex distinction. *Clin. J. Sport Med*. 2007;17(1):31–37.
25. Broglio SP, Macciocchi SN, Ferrara MS. Neurocognitive performance of concussed athletes when symptom free. *J. Athl. Train*. 2007;42(4):504–508.
26. Echemendia RJ, Thelen J, Meeuwisse W, Comper P, Hutchison MG, Bruce JM. Testing the hybrid battery approach to evaluating sports-related concussion in the National Hockey League: A factor analytic study. *Clin Neuropsychol*. 2019;28:1-20.
27. Vartiainen MV, Peltonen K, Holm A, Koskinen S, Iverson GL, Hokkanen L. Preliminary normative study of ImPACT® in Finnish professional male ice hockey players. *Appl Neuropsychol Adult*. 2019;1:1-7.
28. Echemendia RJ, Bruce JM, Meeuwisse W, Comper P, Aubry M, Hutchison M. Long-term reliability of ImPACT in professional ice hockey. *The Clinical Neuropsychologist*. 2016;30(2):328-37.
29. Hurtubise J, Gorbet D, Hamandi Y, Macpherson A, Lauren S. The effect of concussion history on cognitive-motor integration in elite hockey players. *Concussion*. 2016;1(3):CNC17.
30. Esopenko C, Chow TW, Tartaglia MC, Bacopulos A, Kumar P, Binns MA, et al. Cognitive and psychosocial function in retired professional hockey players. *J Neurol Neurosurg Psychiatry*. 2017;88:512–9.
31. Ciesielska N, Sokołowski R, Mazur E, Podhorecka M, Polak-Szabela A, Kędziora-Kornatowska K. Is the Montreal Cognitive Assessment (MoCA) test better suited than the Mini-Mental State Examination (MMSE) in mild cognitive impairment (MCI) detection among people aged over 60? Meta-analysis. *Psychiatr Pol*. 2016;50(5):1039-1052.
32. Trivedi D. Cochrane Review Summary: Mini-Mental State Examination (MMSE) for the detection of dementia in clinically unevaluated people aged 65 and over in community and primary care populations. *Prim Health Care Res Dev*. 2017;18(6):527-528.
33. Park J, Jeong E, Seomun G. The clock drawing test: A systematic review and meta-analysis of diagnostic accuracy. *J Adv Nurs*. 2018;74(12):2742-2754.

34. Delnaz Palsetia, G. Prasad Rao, Sarvada C. Tiwari, Pragya Lodha, Avinash De Sousa. The Clock Drawing Test versus Mini-mental Status Examination as a Screening Tool for Dementia: A Clinical Comparison. *Indian J Psychol Med.* 2018;40(1):1–10.