

Revista Mexicana de Neurociencia



Publicación oficial de la Academia Mexicana de Neurología A.C.

VOLUME 20 - NUMBER 5 / September-October 2019 – ISSN: 1665-5044

eISSN: 2604-6180

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Thrombolysis in Mexico: Current status and opportunities

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With 5.5 million deaths, 80 million prevalent cases, and 116 million disability-adjusted life years, stroke remains the second leading cause of worldwide mortality and adult long-term disability¹. Despite a reduction in stroke mortality in recent decades, given the significant impact of obesity, physical inactivity, and diabetes among other risk factors, the incidence and prevalence of stroke is anticipated to increase, particularly in Hispanics^{2,3}. Therefore, there is a public health imperative to reduce stroke and its attendant disability. Treatment strategies for acute ischemic stroke have made tremendous strides in recent years⁴. Intravenous thrombolytics remain the mainstay, but thrombectomy has now become an important treatment modality⁵.

It is against this background that the work by Arauz et al.⁶ in this issue of the *Revista Mexicana de Neurociencia* should be considered. They prospectively reviewed acute stroke treatment in four hospitals in two large urban areas in Mexico. Each institution had a stroke specialist, a formal stroke program, and a clinical pathway to treatment and follow-up. During the 24-month study period, a total of 500 consecutive ischemic stroke patients were identified. The onset to hospital arrival was 11 h despite a relatively high severity (mean NIHSS 10 ± 6). Of these, 17.4% arrived within 4.5 h from onset and overall 7.6% were treated with intravenous thrombolysis. The mean door-to-needle time was 82 ± 51 min and in 45% the time to treatment was beyond 60 min from hospital arrival. An independent 6-month outcome was noted in 68.4% of those treated versus 41.7% without thrombolytic treatment.

The proportion of stroke patients treated acutely has slowly risen over the past two decades. In the multi-ethnic Florida Stroke Registry, the proportion of acute ischemic stroke patients hospitalized within 24 h from symptom onset and treated within 4.5 h rose from 7% in 2010⁷ to 14% in 2018 [unpublished, floridastrokecollaboration.org]. Similarly, across the US, the quality improvement Get With The Guidelines-Stroke registry reported that 12% of ischemic strokes received alteplase in the 2014-2018 period⁸. Although utilization of thrombolytics for acute stroke in Latin America is not well described, and while recognizing the limitations of hospital registries, it is reassuring to see a similar trend of increased thrombolysis rate in Mexican hospitals: 7.6% reported by Arauz et al.⁶ is an improvement from previously reported 2.4% in the PREMIER study (2005-2006)⁹. Data from 42 mainly European countries estimated a mean annual number of intravenous thrombolysis of 73/1000 annual incident strokes, although some countries achieved rates as high as 175/1000¹⁰. These data provide a benchmarked goal suggesting that the rate of thrombolysis could be as high as 18% if the systems of stroke care were optimized. Given recent data on the efficacy of thrombolysis in neuroimaging-selected cases with unknown time of onset¹¹, rates of treatment may increase further.

Time to treatment is an important driver of outcomes after thrombolysis. A greater effect on good outcomes with no residual disability is observed in the first 3 h

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Date of reception: 04-09-2019

Date of acceptance: 05-09-2019

DOI: 10.24875/RMN.M19000069

Available online: 30-10-2019

Rev Mex Neuroci. 2019;20(5):208-209

www.revexneurociencia.com

(odds ratio [OR] 1.75) compared to the delayed time window (OR 1.26)¹². Moreover, it has been estimated that reducing time to thrombolysis by 15 min is associated with 4% increased chance of independent ambulation at discharge and 4% reduction of in-hospital mortality¹³ and adds 27 days of extra healthy life¹⁴. Quality improvement programs have shown that discreet interventions can be very effective in reducing door-to-needle times^{15,16}. Therefore, the 82-min arrival-to-treatment time reported by Arauz et al.⁶ identifies an opportunity and important short-term target for improvement.

A more challenging problem is getting stroke patients to medical attention in a timely manner. In 2005-2006, data from four US revealed that only 48.0% arrived in hospital within 2 h of stroke symptom onset¹⁷. After a decade from approval of thrombolysis for stroke treatment, only a modest decrease in pre-hospital delays of 6% per year was noted in an international study¹⁸. More recent reports from the State of Florida in the US have shown a persistent average delay of 301 min from symptom onset to 911 call¹⁹. This underlies the importance of more extensive public education on early recognition of stroke symptoms and the urgency of reaching the correct facility for appropriate acute intervention.

The current report by Arauz et al.⁶ has some limitations, including those inherently associated with prospective hospital registries that raise the question of true representativeness. Given the limited number of urban hospitals with availability to stroke expertise, the assumption is that the true utilization of thrombolysis for acute stroke across Mexico is much lower.

Nevertheless, the authors should be commended for contributing to the understanding of the current status of the treatment of acute stroke in Mexico. This contemporary series of consecutive patients identifies important opportunities for improvement. Future change will require a combined and strategic effort from various sectors of society, government, and health care to improve recognition of stroke symptoms, ensure an organized and timely transport to appropriate facilities, and improve in-hospital processes to ensure better outcomes and reduced disability.

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Thrombolytic therapy for acute stroke in Mexico: Experience of four Mexican hospitals

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Abstract

Background: Although the efficacy of intravenous thrombolysis (IV-T) has been widely demonstrated, the rates of its use continue to be low. **Purpose:** The purpose of this study was to assess the frequency of IV-T in Mexican hospitals and to describe the target times for acute treatment and the functional evolution of patients. **Methods:** Data prospectively collected from patients with acute ischemic stroke treated over a period of 2 years in four Mexican hospitals were analyzed. We assessed demographic data, the onset-to-door (OTD) time, the door-to-needle (DTN) time, treatment and the National Institutes of Health Stroke Scale (NIHSS), and modified Rankin scale (mRs) scores at the baseline and at the end of the follow-up. **Results:** There were 500 patients (mean age 57 ± 14 years, 274 [55%] men). The median OTD time was 11 h (range 30 min-190 h); the mean of NIHSS score was 10 ± 6 . Eighty-seven (17.4%) patients arrived at the hospital within 4.5 h; but only 38 (7.6%) patients were treated with IV-T (mean of NIHSS 12 ± 6 points; with a mean OTD time of 2.1 h and a DTN time of 82 ± 51 min). After a median follow-up of 6 months (range 5-24 months), the final NIHSS score was 7 ± 6 points. A better prognosis was observed (mRs < 2) in patients who received IV-T ($p = 0.04$). **Conclusions:** The frequency of IV-T in Mexican hospitals continues to be $< 10\%$. A high percentage of patients continues to arrive at the hospital outside the therapeutic window.

Key words: Acute ischemic stroke. Intravenous thrombolysis. t-PA. Cerebral infarction. Acute.

Terapia trombolítica para el infarto cerebral agudo en México: experiencia de cuatro hospitales Mexicanos

Resumen

Antecedentes y objetivo: Aunque la eficacia de la trombólisis intravenosa (T-IV) está ampliamente probada, las tasas de uso continúan siendo bajas. Nuestro objetivo fue valorar la frecuencia de T-IV en hospitales mexicanos, describir los tiempos meta de tratamiento agudo y la evolución funcional de los pacientes. **Pacientes y métodos:** Los datos demográficos, tiempos de llegada al hospital; puerta aguja (TP-A) y el tratamiento empleado de pacientes con infarto cerebral agudo (ICA) y

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Date of reception: 12-07-2019

Date of acceptance: 22-07-2019

DOI: 10.24875/RMN.19000112

Available online: 30-10-2019

Rev Mex Neuroci. 2019;20(5):210-213

www.revexneurociencia.com

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tratados en 4 hospitales mexicanos fueron recolectados en registros prospectivos de enero de 2017 a enero de 2019. La gravedad y discapacidad se midieron por la escala de NIH y la escala modificada de Rankin (emR). **Resultados:** Analizamos 500 pacientes (media de edad 57 ± 14 años; 274 (55%) hombres). La mediana de tiempo entre el inicio de los síntomas y la llegada al hospital fue de 11 h (rango de 0.30 a 190 min). La media de NIHSS fue de 10 ± 6 puntos. 38 (7.6%) pacientes recibieron T-IV (media de NIHSS 12 ± 6 puntos). En los tratados con T-IV la media de tiempo del inicio de síntomas a la llegada al hospital fue de 2.1 h (127 min) y el TP-A tuvo una media de 82 ± 51 min. Después del seguimiento el NIHSS final fue de 7 ± 6 puntos. Se observó un mejor pronóstico (emR < 2) en pacientes que recibieron t-IV ($p = 0.04$). **Conclusiones:** La frecuencia de T-IV continúa siendo menor al 10%. Un porcentaje elevado de pacientes continúa llegando al hospital fuera de ventana terapéutica.

Palabras clave: Agudo. Infarto cerebral. Terapia trombolítica. t-PA. Trombólisis.

Introduction

Intravenous thrombolysis with tissue plasminogen activator (IVtPA) has improved dramatically overtime and is strongly associated with a good functional outcome. However, its benefit is time dependent with no clear benefit beyond 4.5 h after the time of onset^{1,2}. Despite some initiatives of Mexican medical societies and the recommendations of the different international guidelines, in Mexico, a substantial portion of patients do not receive IV thrombolysis or thrombectomy³. For clinicians, administrators and decision makers who seek to improve the treatment and prognosis of patients with stroke, it is important to know the current situation of acute stroke treatments, as it will allow the implementation of activities and programs that help to reduce the consequences of this devastating disease.

Our objective was to evaluate the frequency of IV thrombolysis in Mexican hospitals with the capacity to administer this treatment. In addition, we assessed the onset-to-door (OTD) and door-to-needle time in treated patients and their association with the clinical outcomes.

Methods

Four participating hospitals in Mexico (Instituto Nacional de Neurología [INNN], Instituto Nacional de Rehabilitación [INR], Hospital Juárez de México [HJM], and Hospital Universitario de Nuevo León [HUNL]) contributed with prospectively collected data from consecutive ischemic stroke patients. The participating centers each have an institutional stroke program for acute care and subsequent follow-up and were recruited through formal invitation due to their known work in stroke care. Data were used primarily at the local site for epidemiological reasons; therefore, the sites were granted waivers for informed consent. The Institutional Ethics Committee of the INNN approved the stroke dataset according to international and local research regulations.

The population consisted of patients with acute ischemic stroke (AIS) treated in participating hospitals from January 2017 to January 2019. Patient data including demographics, medical history, stroke onset (defined as the last known time, at which the patient was well), arrival time (OTD), tPA treatment initiation time (door-to-needle [DTN] time), in-hospital mortality, and ambulatory status at discharge were extracted by trained hospital personnel. Stroke severity was measured by the National Institute of Health Stroke Scale (NIHSS) and the functional outcome was measured by the modified Rankin scale (mRS).

The diagnosis of ischemic stroke was verified by a trainer stroke neurologist and we analyzed data from all patients with a primary stroke diagnosis of ischemic stroke during the study period. Although treatment with thrombectomy is possible in three of the hospitals, only cases treated in one of the hospitals were reported, so for the purpose of the present report, only patients treated with IVtPA were included in the analysis.

To describe patient characteristics, we summarized and compared two groups: patients treated with IVtPA and patients not treated with IVtPA. We analyzed the OTD time in both groups and the DTN time in those treated with IVtPA.

Statistical analyses were performed with SPSS version 19. We performed a descriptive analysis of the different variables, expressed in proportions, medians, and ranges. The proportions of patients with a DTN time of 60 min and clinical outcomes were compared between patients treated with and without tPA.

Results

We analyzed 500 patients (207 from HUNL, 172 from HJM, 92 from INNN, and 29 from INR). The mean age of the population was 57 ± 14 years and 274 (55%) were men. The most frequent risk factors were hypertension in 225 (54%), diabetes in 177 (37%), and

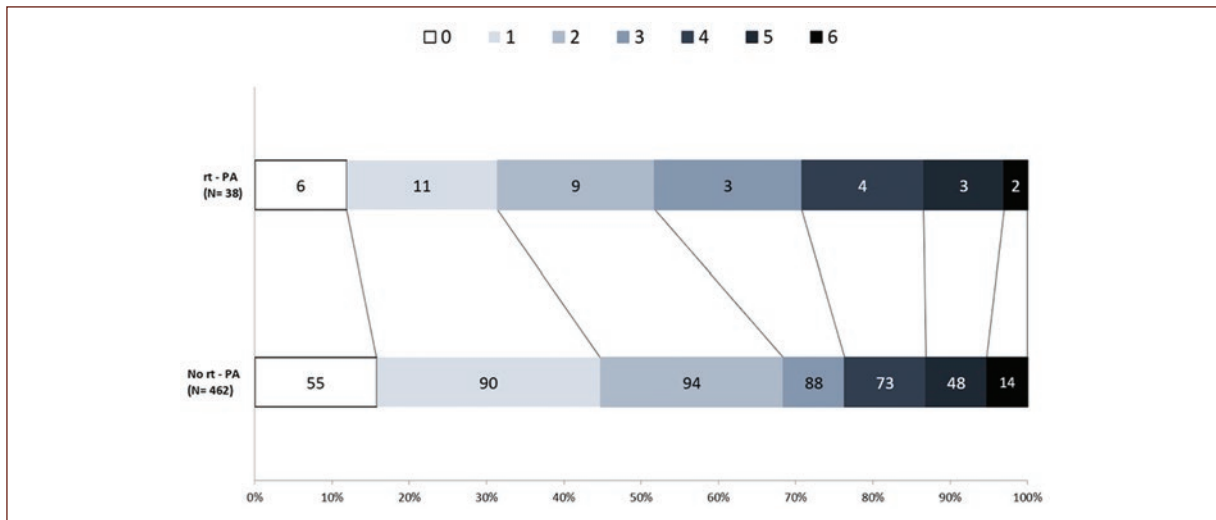


Figure 1. Difference of modified Rankin score scale in groups of patients with and without the use of intravenous thrombolysis with tissue plasminogen activator.

tobacco use in 149 (31%). The mean NIHSS score was 10 ± 6 points.

The median OTD time was 11 h (range: 30 min-190 h). Eighty-seven (17.4%) patients arrived at the hospital in < 4.5 h (median OTD 2.6 h, range 50 min-4.5 h), but only 38 (7.6%) received IVtPA (OTD time; 2.1, range 40 min-4.2 h). In patients treated with IV thrombolysis, the mean DTN time was 82 ± 51 min (range 15 min-3.7 h), and in 17 treated patients (44.7%), the DTN time was longer than 60 min.

Overall, there were 16 (3.2%) in-hospital deaths, and 265 (53%) patients achieved independent functional outcomes at hospital discharge. No cases of hemorrhagic complications were reported.

After a median follow-up of 6 (range 5-24) months, 269 (53%) patients evolved with good functional prognosis (mRs 0-2), 229 (54%) in the group without IV thrombolysis versus 26 (69%) in the treated group (Fig. 1). At the end of the follow-up, the median NIHSS scale score was 6 (range 0-34).

In the comparative analyses, 462 (92%) patients with AIS were not treated with IVtPA, of whom 51% had poor functional outcomes (mRS 3-6). A trend toward better functional outcomes was observed in patients who received IVtPA ($p = 0.04$).

Discussion

This study found that the majority of patients with AIS fail to present to the hospital within the optimal time period for effective intervention. The time of arrival at

the hospital after the onset of symptoms was widely variable, ranging from 30 min to 190 h. Because it was not the objective of the study, we did not analyze what were the causes of the delay, but it could be explained by the failure to recognize the signs and symptoms or a lack of awareness of potential treatment benefits. Hospitals also failed to have an adequate organization for the treatment of these patients; among those who arrived within the therapeutic window, less than half received treatment with tPA and in more than half the patients who were treated, the DTN time was > 60 min, with a wide range.

The lack of improvement in the delay in stroke evaluation and treatment underscores the need for more effective public health programs in Mexico. Further, efforts to increase public awareness of stroke signs and symptoms, to disseminate guidelines and recommendations for stroke evaluation and treatment, and to develop initiatives (including those targeting health-care providers, the emergency medical system, telemedicine, those implementing a pre-hospital acute stroke protocol and the public) are imperative to change this scenario in Mexico and in most other middle- and low-income countries.

In positive trials, patients were treated at hospitals with complex, efficient, resource-rich, team-based stroke systems in place, in which the implementation of a national quality improvement initiative was associated with improved timeliness of tPA administration, and this improvement was associated with lower in-hospital mortality and intracranial hemorrhage⁴.

Developed countries have greatly reduced mortality and dependence mainly due to changes in case fatality; however, there has been limited progress in the acute stroke management in developing countries^{5,6}. This could be attributed to several reasons mainly relating to limited health-care resources for the population, socioeconomic considerations, pre-hospital delay, and lack of infrastructure. Although in Mexico, the use of IVtPA seems to have been increased in recent years², its frequency of use continues to remain low, and hospital arrival and treatment times remain far below the international standards. In contrast, to our results, a previous study in Mexico showed that a high percentage of patients had short hospital arrival times; however, less than 3% underwent thrombolysis². Three of the participating hospitals included patients in both registers, so it is significant that the percentage of patients treated with IVtPA, in these centers, increased from 3% to 7% in a period of 10 years.

While the previous studies demonstrated that educational efforts to improve the recognition of stroke symptoms have been shown to reduce the time to hospital arrival after symptom onset⁶⁻⁸, additional educational initiatives are still needed in Mexico.

Our study has multiple limitations. The main limitation is that it is a representative sample of two of the main cities in Mexico, and the results are biased toward urban settings with reasonably well-developed health-care systems. As in most developing countries, in Mexico, the quality of stroke care varies widely, with areas of excellence, intermixed with areas of severe need, depending on the location, socioeconomic status, education, and cultural beliefs of the region. Another limitation is that although the subjects were consecutive patients in a prospectively maintained database, the retrospective analysis does not allow the evaluation of other variables of interest, such as door-to-tomography time, and the causes of delay.

Our data provide a national perspective on acute stroke care and should inform the planning and optimization of stroke systems in Mexico to promote public awareness of the benefits of prompt stroke treatment.

The recognition of stroke warning signs and the time window during which reperfusion is therapeutically effective is undoubtedly an area of opportunity in Mexico.

Conclusion

The frequency of IV-T in Mexican hospitals continues to be less than 10%. A high percentage of patients continues to arrive at the hospitals outside the therapeutic window.

Conflicts of interest

The authors of this article do not have conflicts of interest to declare.

Financing

This article does not require funding sources, if required, would cover the costs generated from the research fund of the Stroke Clinic of the National Institute of Neurology and Neurosurgery of Mexico.

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Neurofunctional activation patterns reflect differences in cognitive control associated with spelling skills in Spanish

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Abstract

Introduction: There is an essential relationship between reading development and orthographic knowledge, which varies depending on a language's orthographic characteristics. In transparent orthographies, such as Spanish, that relationship is closer, where reading speed and orthographic knowledge reflect the automation of the process in which crucial participation of attention networks is assumed. **Objective:** The objective of this study is to compare behavioral performance and patterns of cerebral functional activity while subjects with high and low orthographic knowledge perform an attentional control task involving word recognition. **Methods:** Thirty right-handed participants, aged between 17 and 20 years, were selected through non-probabilistic sampling and then classified into two groups according to their level of orthographic knowledge: high (H) and low (L). Neurofunctional activity was recorded using fMRI methods during the execution of a Stroop task (words printed in color congruent and incongruent with their meaning) under two conditions: attending to the meaning (automatic processing) or the color (interference condition). **Results:** The L group showed greater reaction times in both conditions, as well as greater functional activity in subcortical areas. In contrast, the H group showed higher activity in cortical areas, such as left supramarginal gyrus and medial frontal gyrus in the automatic processing condition, and in the parietal lobe during interference. **Conclusions:** The more significant activity in the giro frontal medial of the high orthographic knowledge group could imply recruitment of greater attention and cognitive control resources, while the neurofunctional activity observed in the low group could be associated with a compensatory effect with the recruitment of subcortical areas to solve the task.

Key words: Orthographic knowledge. Stroop task. Attentional control. Functional magnetic resonance imaging. Reading.

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Date of reception: 30-06-2018
Date of acceptance: 23-10-2018
DOI: 10.24875/RMN.M19000062

Available online: 30-10-2019
Rev Mex Neuroci. 2019;20(5):214-221
www.revexneurociencia.com

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La actividad funcional cerebral caracteriza el control cognitivo asociado a habilidades ortográficas en el idioma español

Resumen

Introducción: Existe una importante relación entre el desarrollo de la lectura y el conocimiento ortográfico, la cual varía en dependencia de las características ortográficas de la lengua. En ortografías transparentes, como el español, esa relación es más estrecha, donde la velocidad de lectura y el conocimiento ortográfico reflejan la automatización del proceso, en la que se asume una participación importante de las redes atencionales. **Objetivo:** Comparar los patrones de actividad funcional cerebral en una tarea de control atencional que involucra el reconocimiento de palabras, en sujetos con alto y bajo conocimiento ortográfico. **Método:** Se usó un muestreo no probabilístico para seleccionar a 30 jóvenes, diestros, en un rango de edad entre 17 y 20 años, clasificados en dos grupos de acuerdo con su nivel de conocimiento ortográfico: alto y bajo. Se registró la actividad neurofuncional usando IRMf, durante la ejecución de una tarea de Stroop (palabras impresas en color congruente e incongruente con su significado). Los participantes procesaron las palabras en dos condiciones: atender al significado (procesamiento automático) o al color (condición de interferencia). **Resultados:** El grupo con «bajo» rendimiento ortográfico mostró mayores tiempos de reacción en la ejecución de ambas condiciones, así como mayor actividad funcional en áreas subcorticales. El grupo alto mostró la actividad esperada en áreas corticales como el giro supramarginal izquierdo (GSI) y giro frontal medial (GFM) durante el procesamiento automático de las palabras, mientras que en la condición de interferencia se observó mayor actividad en lóbulo parietal. **Conclusiones:** Diferencias en las habilidades ortográficas derivan en distinta activación funcional, donde una mayor actividad en GFM del grupo «alto» pudiera implicar el reclutamiento de mayores recursos atencionales y de control cognitivo, mientras que la actividad neurofuncional observada en el grupo «bajo», podría asociarse con un efecto compensatorio con el reclutamiento de áreas subcorticales para resolver la tarea.

Palabras clave: Conocimiento ortográfico. Stroop. Control atencional. IRMf. Lectura.

Introduction

Reading automation is a complex developmental process that makes reading faster and less effortful, while minimizing attention and memory requirements consequently enhancing reading comprehension. There is a close relationship between reading and orthographic integration which seems to depend on the orthographic transparency of the language^{1,2}. In transparent orthographies, such as Spanish, where there is a close relationship between graphemes and phonemes, impairments in reading speed and spelling problems occur frequently, and these orthographic difficulties may endure into adulthood³⁻⁵.

Despite increasing evidence regarding reading fluency and orthographic abilities in children, few studies have explored this association in late adolescence and adulthood. A recent study performed in Spanish-speaking young adults reported significant supramarginal and angular gyrus activations while actively recognizing orthographic errors⁶. These regions are involved in the interactions between the phonologic and orthographic representations of words⁷.

An emerging question in the current psycholinguistic research is how attentional control systems can influence specific components of the lexical processing system.

In this regard, skilled reading in adults has been extensively studied using variations of the Stroop task^{8,9}. The incongruence between word meaning and the color in which a word is printed usually elicits slower response times due to interference with the automatic word-recognition process, and the Stroop interference effect has been related to attentional control.^{8,10-12} The left medial frontal gyrus (MFG) plays an important role in attentional control via a top-down biasing when selecting task-relevant stimuli and through inhibition of task-irrelevant stimuli¹³. In this context, the aim of the present study was to comparatively evaluate behavioral and brain activation patterns during performance of a Stroop task in a sample of young adult readers with different levels of orthographic processing skills, in order to discern whether the lower level of reading automation seen in individuals with low orthographic skills associates with attentional control and mapping processes between phonological and orthographic word representations.

Methods

Participants

A non-probabilistic convenience sampling method was used for the assessment. Thirty young adults

Table 1. Demographic data, orthographic knowledge, and behavioral results while performing the experimental task

	HSS	LSS	t (df)	p
	Mean (SD)	Mean (SD)		
Demographic data				
Age	18.6 (0.98)	18.7 (0.90)	t (27.7) = -0.2	n.s.
Estimated IQ	107.7 (8.8)	101.3 (5.2)	t (22.5) = 2.4	n.s.
Orthographic knowledge				
Reading speed	165.3 (23.8)	133.6 (25)	t (20.4) = 4.4	< 0.001
Reading errors	0.9 (1.7)	8.5 (6.1)	t (16.2) = -4.6	< 0.001
Reading comprehension	7.9 (2.1)	6.6 (2.4)	t (27.3) = 1.6	n.s.
Orthographic errors	7.2 (3.0)	35.2 (0.7)	t (15.4) = -34.9	< 0.001
Interference task results				
Word meaning correct responses	33.2 (6.9)	33.1 (5.8)	t (28) = 0.02	n.s.
Word color correct responses	35.2 (5.5)	35.9 (2.3)	t (28) = -0.4	n.s.
Word meaning reaction time	780.5 (88.8)	855.1 (103.9)	t (28) = -2.1	0.044
Word color reaction time	770.5 (112.7)	842.7 (108.7)	t (28) = -1.8	n.s.

df: degrees of freedom; SD: standard deviation; n.s.: not significant.

whose ages ranged from 17 to 20 years ($M = 18.63$ years, $SD = 0.928$; 10 females) participated during 2017; all were right-handed as assessed by the Edinburgh Handedness Inventory and had normal or corrected-to-normal vision¹⁴. None had any personal or family history of psychiatric, neurological, or degenerative illness, nor diagnoses of ADHD, emotional disturbances, or behavioral disorders, according to the DSM-V criteria¹⁵. They all signed an informed consent form and received economic compensation for their participation, following permission and recommendations of the Ethics Committee of the *Instituto de Neurociencias (Universidad de Guadalajara)*, which approved the study.

The sample was obtained from a pool of 380 students in the final year of high school (public) or the first semester at a public university. Participants were divided into two groups according to their performance on four orthographic knowledge tasks from the *Batería de Conocimiento Ortográfico (BCO, orthographic knowledge test)*¹⁶. These tasks involved word completion (complete words by choosing between two or three homophone letters), text dictation (a narrative text in the form of a letter), word dictation (a list of 40 words all susceptible to pseudohomophone errors), and text correction exercises (an expository text in which 22 words were replaced by pseudohomophonic errors). The BCO is a four-test battery validated for high school students, with a Cronbach's internal consistency reliability of $\alpha = 0.859$, and a construct validity analysis showing that all tests contribute to a single construct that explains 71% of total

variability. A previous study with a sample of 827 native Spanish-speaking young adults demonstrated that BCO had a very high discriminability in terms of distinguishing groups with different orthographic abilities ($t = 11.608$; $p < 0.001$)¹⁶.

Groups were formed as follows: high spelling skills (HSS), 15 participants (6 females) with fewer errors than those corresponding to the 10th percentile of the standardized BCO scores, and low spelling skills (LSS), 15 participants (4 females) with a number of errors above the 90th percentile. All subjects had a global IQ ≥ 90 as measured by a short version of the Wechsler Adult Intelligence Scale III¹⁷. Due to excessive head movements during the functional magnetic resonance imaging (fMRI) recording session, one female participant from the LSS group had to be excluded from further analysis.

The groups were matched according to age and educational level. All participants underwent an extensive clinical interview before the experimental sessions. Prior to the neuroimaging studies, and due to the strong relationship found between spelling difficulties and low reading fluency, we decided to explore whether LSS also had problems related to reading accuracy or speed¹⁸. Consequently, all subjects were asked to read aloud an expository text of 504 words as quickly and accurately as possible. Table 1 shows the demographic characteristics, orthographic knowledge profiles, and reading test performance of all subjects.

During the MRI scan session, participants performed a variant of the Stroop task in which the words green, blue, and red appeared printed in congruent or

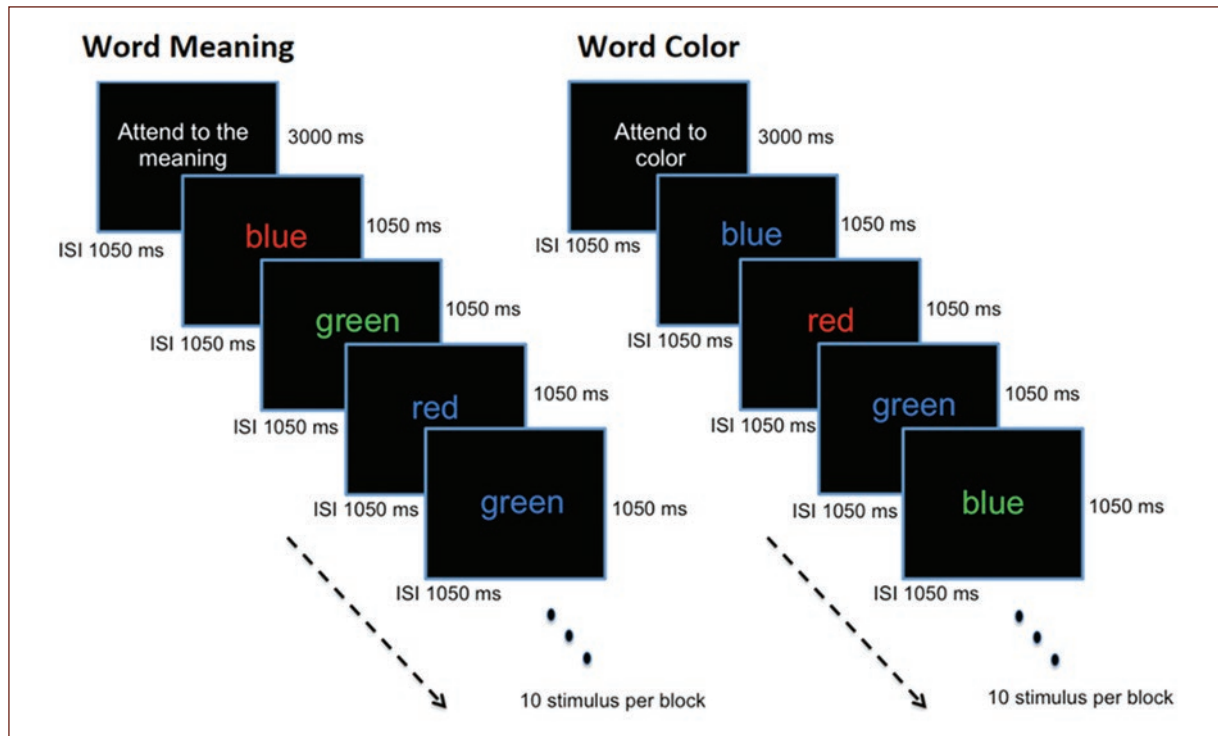


Figure 1. Experimental flowchart. In word meaning, the participants are instructed to press one button to identify the color denoted by the word presented on the screen. In word color, they are instructed to press the button that corresponds to the color in which the word shown is printed (e.g., when the word red appears printed in blue, the subject should press the button that corresponds to the blue option).

incongruent colors. The tasks were identified as word meaning and word color, and their presentation order was counterbalanced. In word meaning, subjects had to read the word and identify its meaning by pressing a corresponding button. In word color, they were instructed to press a button that indicated the color in which the word was printed while ignoring the meaning of the word that appeared. [Figure 1](#) illustrates the experimental design.

Procedure

During the fMRI scans, the stimuli were administered using E-Prime Studio v.2.0 (Psychology Software Tools, Inc., 2010). Images were projected through a Google system, and responses were collected using a magnetic -resonance-compatible, handheld, four-button response pad connected to the computer by an optical cable interface.

Days before the scanning session, task instructions were presented and explained to the subjects during their assessment session. Subjects then performed several series of training trials with feedback provided to familiarize them with the task. All subjects were

instructed as to the arrangement of the keypad buttons, which represented green, blue, and red from left to right. They were told to use the index, middle, and ring fingers of their right hand to respond. They were also instructed to respond as quickly as possible while keeping in mind that the main goal was to perform the tasks correctly.

Both tasks were administered through a block design with 8 activation blocks. Blocks were separated by resting periods. During the resting periods, the participant focused on a fixation point presented at the center of the screen. Prior to each activation block, an instruction lasting 3000 ms was presented. Both stimulus and interstimulus intervals lasted 1050 ms, resulting in 80 trials with a total duration of 6 min 12 s and 10 stimuli per active block ([Fig. 1](#)). A total of 124 brain volumes were obtained from each experimental task, but 12 were eliminated from the subsequent statistical analysis. The first two volumes discarded contained the warnings that preceded the beginning of the task. Furthermore, the volumes corresponding to the instructions preceding each of the 8 active blocks were deleted. The other 2 discarded volumes were those used to inform subjects that they had completed the task.

Image acquisition

A GE Excite HDxT 1.5 Tesla device (GE Medical Systems, Milwaukee, WI, USA) with an 8-channel head coil was used. For each experimental task, 32 contiguous axial slices were obtained (4 mm thick). An echo-planar pulse sequence was used with a repetition time of 3 s, echo time of 60 ms, flip angle of 90°, FOV of 25.6 cm, and a 64 × 64 matrix. Voxel size was 4 × 4 × 4 mm.

Data analysis

The demographic and behavioral results were analyzed using SPSS 20.0. An Independent Samples t-test was performed to compare the two conditions within the groups. Spatial preprocessing and statistical inference of the images were carried out using the SPM12 computer package (<http://www.fil.ion.ucl.ac.uk/spm/software/spm12/>). The images were spatially realigned, readjusted to the voxel size, and normalized in accordance with the Montreal Neurological Institute reference. For smoothing, a kernel Gaussian filter 3 times the voxel size was used on the x, y, and z axes.

Brain activations in response to the two conditions were examined by performing a first-level general linear model (GLM) analysis for each subject using a statistical threshold of $p = 0.05$. To compare activation patterns between the groups and conditions, a second-level GLM analysis was conducted using the same statistical threshold for cluster level and applying posterior correction with a Bonferroni procedure to reduce nominal type I error.

Results

Reading performance

Reading performance was analyzed by an independent t-test, assuming equal variances (Levene test: $F = 0.808$; $p = 0.376$). A significant difference in reading speed was found between the groups ($t(20.4) = 4.4$; $p = 0.001$; $r = 0.639$), with a greater number of words per minute and fewer reading errors in HSS than LSS (Table 1).

With respect to reading comprehension, and assuming equal variances (Levene test: $F = 1.073$; $p = 0.309$), no significant differences were found between the groups ($t(27.3) = 1.60$; $p = 0.119$; $r = 0.289$), though the number of correct responses achieved by HSS was slightly higher than in LSS.

Behavioral paradigm results

For the experimental task, we analyzed two variables using independent t-tests: the number of correct responses and response times (RTs). We only found significant between-group differences in the RT word meaning condition ($t(28) = -2.11$; $p = 0.044$; $r = 0.361$), assuming equal variances (Levene test: $F = 0.592$; $p = 0.448$). LSS showed slower RT in both conditions (word meaning and word color) than HSS, but only RT during word meaning differed significantly. Accuracy between the groups, in contrast, was similar in both conditions (Table 1).

Neuroimaging results

Tables 2 and 3 show the main activation clusters observed in the experimental groups during task performance. As was expected, main between-group differences involved the left supramarginal gyrus (LSG) and MFG, both of which were highly activated in HSS during recognition of word meaning. This group also involved the superior parietal lobe together with other right cortical structures while processing the word interference task (word color). In contrast, LSS did not show significant activations at LSG and MFG while performing the experimental tasks. Predominantly, LSS showed subcortical activations, primarily involving cerebellar structures. Figure 2 shows the main BOLD activated structures in both the groups while processing the word meaning and word color task sections, respectively.

Discussion

The present study evaluated the behavioral and brain activation patterns of Spanish-speaking young readers with different levels of orthographic processing skills during performance of an interference task. One of our objectives was to assess whether lower orthographic processing skills in Spanish might reflect a deficit in attentional control.

At first, and unsurprisingly, LSS showed slower reading speeds, thus confirming the significant relationship between spelling knowledge and reading speed reported for transparent orthographies^{3,19}. Both spelling performance and reading speed are important factors for the development of reading and writing. In addition, several studies have observed problems in spelling and reading speed in subjects with reading disorders, even in adults who had reached high educational levels^{20,21}. It has been proposed that these problems may be due to a unique mechanism that underlies the ability to store

Table 2. Brain functional activations per condition in the high skill spelling group

Task	Cluster	Z	MNI coordinates			H	Brain region	Brodmann area
			x	y	z			
Word meaning	1532	4.36	-46	-32	46	L	Supramarginal gyrus; Middle frontal gyrus	40, 6
	464	3.74	6	-60	-22	R	Cerebellar culmen (anterior lobe); Cerebellar tonsil (posterior lobe)	*
	197	3.00	50	12	18	R	Inferior frontal gyrus; Middle frontal gyrus	6, 44, 46
	120	3.00	38	-56	46	R	Supramarginal gyrus; Superior parietal lobule	40, 7
	115	2.34	-38	-64	-30	L	Cerebellar tuber; cerebellar declive (posterior lobe)	*
Word color	1821	5.42	-42	-32	46	L	Supramarginal gyrus; Superior parietal lobule	40, 7
	1089	4.59	38	-60	-30	R	Cerebellar tuber (posterior lobe); Cerebellar pyramid (anterior lobe)	*
	270	4.00	38	-56	50	R	Superior parietal lobule; Inferior parietal lobule	7, 40
	234	3.43	58	12	34	R	Middle frontal gyrus	9, 6

H: hemisphere; L: left; R: right.

Table 3. Brain functional activations per condition in the low skill spelling group

Task	Cluster	Z	MNI coordinates			H	Brain region	Brodmann area
			x	y	z			
Word meaning	113	2.76	18	-60	-26	R	Cerebellar dentate (anterior lobe); Cerebellar pyramid (posterior lobe)	*
	11	2.12	-42	-56	-26	L	Cerebellar tuber	*
	10	2.01	-34	16	-6	L	Inferior frontal gyrus	47
Word color	423	3.67	26	-52	-34	R	Cerebellar tonsil; Cerebellar inferior semilunar lobe	*
	38	2.69	-34	0	22	L	Precentral gyrus; Superior temporal gyrus	6, 22
	41	2.29	34	24	-6	R	Inferior frontal gyrus	47

H: hemisphere; L: left; R: right.

representations of the written form of words in long-term memory and thus facilitates the process of reading and the efficient recovery of that material²².

Paradoxically, there were no significant interference effects during the word color assignment in either group. Here, several factors may have been involved: the low number of stimuli; the training received before task performance; the time that each word was shown; the way in which the stimuli were delivered; and the response modality of button pressing which is different from a typical Stroop task in which words/colors are produced aloud, among several other possible influences. Having said this, the behavioral results obtained while performing the MRI scanning may not

comparably reflect what a representative Stroop task performance might yield under regular conditions.

Turning to our behavioral results, LSS showed significantly longer reaction times than HSS during both the word meaning and word color tasks. Given that slow reading speed is the core element of reading disabilities in Spanish, LSS' performance in our study seems to coincide with previously reported findings in people with reading disorders^{9,10,23,24}.

Taken together, the results of the present study suggest that slower performance observed in LSS might extend to non-linguistic processing of printed words and probably reflects an additional deficit in the mechanisms of attentional control.

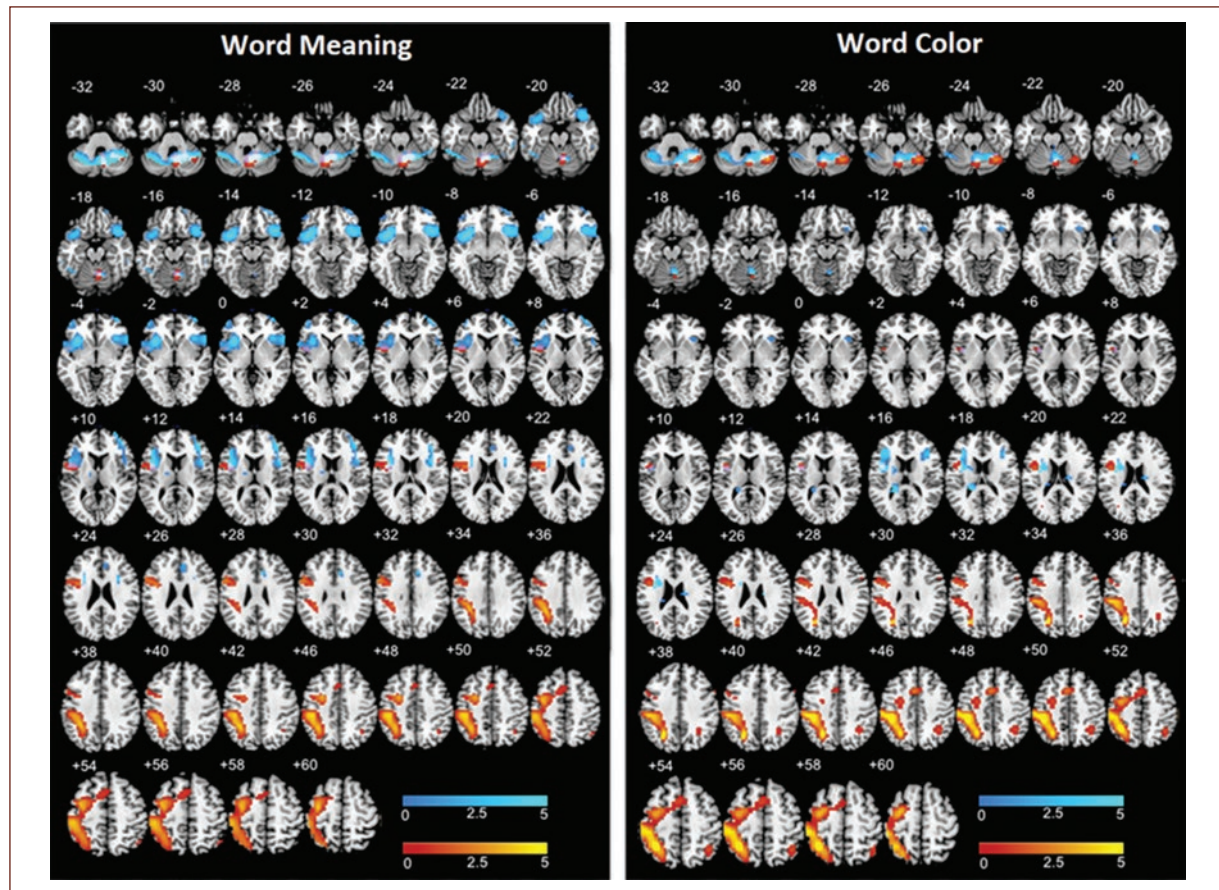


Figure 2. Functional neuroimages for the word meaning and word color conditions. Neurological view (left-right). Red-to-white colors represent the statistical activity (z) of the HSS group. Blue-to-white colors represent the statistical activity (z) of the low spelling skills group.

As hypothesized at the outset, neurofunctional correlates of task performance differentially involved the LSG and MFG of the two study groups. This emphasizes that attention and word recognition processes are the main foundations of the more developed spelling abilities in native Spanish-speaking young adults. In contrast, our LSS subjects mainly activated subcortical areas involving cerebellar regions that have been linked to language processes, especially when articulation is a factor to be considered²⁵. This also occurs with the insula, another area that has been linked to many linguistic processes, including language production, repetition, and naming²⁶.

In fact, our LSS individuals showed significant activations in cerebellar and posterior frontal cortical areas while processing the interference task. These regions have been related to executive functions and attentional control²⁷. The left caudate and cerebellum have been associated with the suppression of irrelevant words while performing interference tasks²⁸. In addition, the left

caudate has been closely associated with the cingulate gyrus (which in turn has been related to conflict monitoring), and with other structures related to perception and the visual recognition of stimuli and letters, including the fusiform, lingual, and inferior occipital gyri²⁹.

Although the lack of a clear interference effect might limit the scope of the present study, the neurofunctional differences detected between the groups: (1) indicate that both attentional control and word management are involved in solving interference while reading and (2) distinguish the level of orthographic processing in native Spanish-speaking young adults. However, further studies are required to fully understand the relation between these variables in a transparent language such as Spanish.

Conclusions

The subcortical and cerebellum involvement observed in LSS might reflect an adaptive effort to recruit additional processing resources in order to fulfill task

requirements. Furthermore, the increased activity observed in the left MFG in HSS might reflect a higher level of attention and cognitive control, as postulated by Egner and Hirsch³⁰.

Conflicts of interest

None of the authors have potential conflicts of interest to be disclosed.

Funding

The research presented in this paper was supported by grant to second author from SEP-CONACYT Mexico (183561).

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Epidemiological characteristics of Dementia-related mortality in Mexico between 2012 and 2016

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Abstract

Introduction: Dementia refers to a group of neurodegenerative disorders characterized by progressive deterioration of cognitive skills and is one of the main pathologies associated with disability and dependency among older adults. **Objective:** The objective of the study was to analyze the relationship between the demographic factors and mortality from dementia in the Mexican population. **Methods:** This was a population-based, retrospective, and cross-sectional study. We employed an open-access national dementia-related mortality dataset. **Results:** The overall mortality rate in Mexico was 0.16/1000 inhabitants. The mean age of mortality was 84.37 ± 0.10 years. In the statistical analysis, sociodemographic variables that were associated with greater mortality due to dementia were age > 80 (OR 2.91, $p < 0.001$), single (OR 1.66, $p < 0.001$), female (OR 1.53, $p < 0.001$), an urban area (OR 1.42, $p < 0.001$), to have higher education (OR 1.23, $p = 0.001$), and residency in large cities (OR 1.33, $p < 0.001$). **Conclusions:** Mortality from dementia arises as a cosmopolitan phenomenon associated with socioeconomic factors.

Key words: Dementia. Epidemiology. Mortality. Aged.

Características epidemiológicas de la mortalidad por demencia en México durante los años 2012-2016

Resumen

Introducción: La demencia se refiere a un grupo de trastornos neurodegenerativos caracterizados por un deterioro progresivo de las habilidades cognitivas y es una de las principales patologías asociadas con la discapacidad y la dependencia entre los adultos mayores. **Objetivo:** Analizar la relación entre los factores demográficos y la mortalidad por demencia en la población Mexicana. **Métodos:** Estudio poblacional, retrospectivo, transversal. Se empleó un conjunto de datos nacionales de mortalidad asociada a la demencia de acceso abierto. **Resultados:** La tasa de mortalidad general en México fue de 0.16 por cada 1000 habitantes. La edad media de mortalidad fue de 84.37 ± 0.10 años. En el análisis estadístico, las variables sociodemográficas que se asociaron con una mayor mortalidad por demencia fueron: edad > 80 (OR 2.91, $p < 0.001$),

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Date of reception: 26-11-2018

Date of acceptance: 30-04-2019

DOI: 10.24875/RMN.19000003

Available online: 30-10-2019

Rev Mex Neuroci. 2019;20(5):222-228

www.revexneurociencia.com

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solteros (OR 1.66, $p < 0.001$), mujeres (OR 1.53, $p < 0.001$), área urbana (OR 1.42, $p < 0.001$, tener educación superior (OR 1.23, $p = 0.001$), residir en ciudades grandes (OR 1.33, $p < 0.001$). **Conclusiones:** La mortalidad por demencia surge como un fenómeno cosmopolita asociado a factores socioeconómicos.

Palabras clave: Demencia. Epidemiología. Mortalidad. Adulto mayor.

Introduction

The aging of the population worldwide is a process without precedents in human history provoking an increase in the prevalence of chronic illnesses¹. In Mexico, aging is a phenomenon that has emerged and is progressively advancing in a non-homogenous way within different federative entities². The population pyramid of the country in the year 2015 was reported to have widened at the center and reduced at the base; moreover, the population of age 15 years or less represents 27% of the total population; in comparison, persons of age 15-65 years constitute 65% of the total population³.

According to the National Population Council (*Consejo Nacional de Población*, CONAPO), it is estimated that by 2030 the aged population will constitute 14.9% of the total population; therefore, it will be considered as a population transition, and by 2050 it will be an aged population with 24.7% of the elder. This population-based phenomenon comes as a result of the increasing number of patients with chronic degenerative diseases posing new health-care challenges.

Dementia refers to a group of neurodegenerative disorders characterized by a progressive deterioration in cognitive abilities, such as memory and reasoning, and dysfunction in the ability to live independently among those affected⁴. The most representative causes of dementia include Alzheimer's disease (50-60%), vascular dementia, Lewy body dementia, and frontal-temporal degeneration⁵.

In 2013, it was estimated that 44 million people were suffering from dementia worldwide, with 7.6 million new cases annually. It is believed that the number of people with dementia will double every 20 years reaching 76 million by 2030 and 135 million by 2050 worldwide, this increase will be more marked in developing regions than in developed regions⁵. Mexico has experienced a continuous increase in life expectancy having as a consequence a proportional increase of geriatric population, for that reason, dementia prevalence might also be rising. At present, there are some clinical reports estimating that of 500-700 thousand people with dementia, approximately 25% have not been diagnosed⁶.

Dementia, stroke, and depression are considered to be illnesses that affect the brain and mental health;

thus they constitute the main contributors to disability and dependence among older adults. However, these conditions receive less priority than cardiovascular illnesses and cancer, which have an earlier impact on mortality⁵. This pathology increases the risk of mortality among the general population. There are several sociodemographic factors that have been related to the increased risk of mortality due to dementia, such as gender, age, level of education, civil status, ethnic group, geographic location, and temporality^{1,7-10}.

In Mexico, there is little, if any, information available about the sociodemographic factors most frequently associated with mortality due to dementia; for this reason, the objective of the present study is to analyze the relationship between the sociodemographic factors and the mortality due to dementia in the Mexican population during the period between 2012 and 2016.

Materials and methods

An observational retrospective cross-sectional study was conducted. The mortality data were obtained from the national mortality database provided by the National Institute of Statistical Geography (*Instituto Nacional de Geografía y Estadística*, INEGI) from 2012 to 2016, which derives from the General Direction of Health Information that in a stage by stage collection and verification process registers the information from the death certificates nationwide with validation from the epidemiology department. Patients older than 65 years with a diagnosis of dementia as the cause of the death ($n = 6499$) were selected from each database per year. Cases of dementia were included for the present study based on the International Disease Codes, tenth revision that pertains to ICD-10 codes F000-F0X3. The rate of mortality due to dementia at the national level and by the state was calculated by taking the number of dementia cases and dividing them by the mid-year number of inhabitants. The population size and inhabitant numbers were obtained from the population projections issued by the CONAPO, the result of the division was subsequently multiplied by 1000 to obtain the mortality rates per 1000 inhabitants³. To carry out a comparative statistical analysis, each dementia-related

mortality case was paired with a randomly selected, non-dementia related mortality case. The sociodemographic variables that were evaluated included: age, gender, indigenous language, marital status, schooling, current profession, area of residence (rural, urban), affiliation, medical insurance, month of occurrence, and the population size of inhabitancy. The age was transformed as a continuous variable calculated by subtracting the date of birth from the date of death and dividing the result by 365.25. Indigenous ethnicity, marital status (with or without couple), schooling (equal to or more than high school or less than high school level), current occupation, area of residence (rural or urban), and entitlement were coded as present or absent dichotomous variables. The month of occurrence refers to the month in which death occurred. The size of the locality refers to the number of people that inhabit the place where the death occurred¹¹.

Statistical analysis

The descriptive statistics including the totals, proportions, and frequencies were obtained from the categorical and ratio variables. In addition, the central tendency and dispersion measures were obtained from the numerical variables. Statistical significance was evaluated through statistical hypothesis tests, by comparing proportion for nominal variables (Chi-squared) and mean-comparison tests for numerical data (student's t-test). Subsequently, logistic regression modeling was performed when dependent variables were binary, and odds ratio (OR) was calculated¹². All the statistical analyses were conducted using the program *Stata 14*®, values with $p < 0.05$ were taken as statistically significant.

Results

Between 2012 and 2016; 6192 deaths due to dementia were recorded in Mexico among population over 65 years. [Figure 1](#) displays the dementia-related mortality rate per 1000 inhabitants, per year among ≥ 65 years during the period 2012-2016. The total death rate in Mexico during the same period was 0.16/1000 habitants. [Figure 2](#) displays the population of the country per year during the same period. Moreover, this figure indicates that there was a considerable increase in the population of persons aged 65 years or more each year, unlike the death rate due to dementia, which was constant except for a small increase in the year 2015. In the entity analysis, it was observed that the

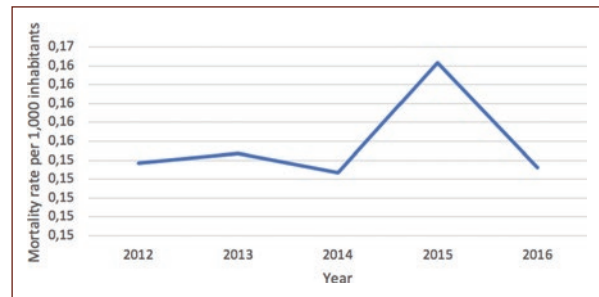


Figure 1. National rate of mortality due to dementia 2012-2016.

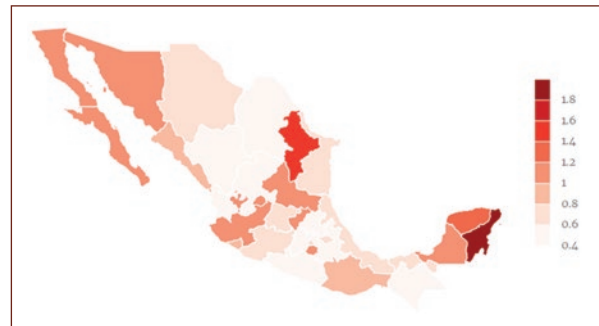


Figure 2. Incidence rate of dementia-related mortality per 1,000 inhabitants in Mexico, between 2012-2016.

states Nuevo León, Quintana Roo and Yucatán occupy the first three places in death rate in descending order ([Fig. 2](#) and [Table 1](#)).

The sociodemographic characteristics related to deaths due to dementia are displayed in [Table 1](#). The average age of the population living with dementia was observed to be 84.37 ± 0.10 years which is significantly different from those whose established cause of death was not due to dementia (79.32 ± 0.12 years).

Nearly 27.13% of dementia-related cases were found to be within the age range of 65-79 years, 70.62% within the age range of 80-99, and 2.24% were older than 100 years. The proportion of the population with dementia differed by gender; it was observed that dementia was more prevalent in female (60.47%) compared to male (39.53%).

Mortality due to dementia predominates in economically active people (84.71%) at the time of death, with any grade of education (73.79%), specifically less than bachelor degree (88.55%), with entitlement (80.12%), and medical care (80.19%) at the time of death, living among populations $< 500,000$ people (61.51%) and living in urban areas (81.72%). 8.75% of

Table 1. Sociodemographic characteristics of the population n = 12384

Variable	Dementia n = 6192		Without dementia n = 6192		p < 0.05
	Proportion (n)	Mean $\pm$ SD	Proportion (n)	Mean $\pm$ SD	
Age		84.37 $\pm$ 0.10		79.32 $\pm$ 0.12	< 0.001
Population > 500 thousand	38.49 (2383)		31.94 (1978)		< 0.001
Population < 500 thousand	61.51 (3809)		68.06 (4214)		< 0.001
Male	39.53 (2448)		50.05 (3099)		< 0.001
Female	60.47 (3744)		49.95 (3093)		< 0.001
Economically active	84.71 (4979)		85.31 (5031)		0.355
Not economically active	15.29 (672)		14.69 (866)		0.355
Education	73.79 (4331)		69.53 (4070)		< 0.001
$\geq$ High school	11.45 (672)		9.53 (558)		0.004
< High school	88.55 (5197)		90.47 (3323)		0.004
With partner	32.64 (1970)		44.64 (2680)		< 0.001
Without couple instead of partner	67.36 (4065)		55.48 (3435)		< 0.001
Medical insurance	89.19 (5272)		88.50 (5152)		0.308
Without medical insurance	80.12 (4522)		80.41 (4541)		0.695
Urban area	81.72 (5034)		75.90 (4659)		< 0.001
Rural area	18.28 (1126)		24.10 (1479)		< 0.001
Indigenous ethnicity	8.75 (463)		11.41 (602)		< 0.001
65-79 years	27.13 (1680)		53.18 (3293)		< 0.001
80-99 years	70.62 (4373)		45.20 (2799)		< 0.001
> 100 years	2.24 (139)		1.51 (100)		0.005

SD: standard deviation.

the population belonged to an indigenous ethnicity at the time of death.

In the logistic regression analysis of binary dependent variables (Table 2), the sociodemographic characteristics that were directly associated with greater mortality due to dementia were: age > 80 years (OR 2.91, $p < 0.001$), (please note that age older than 100 years showed OR 1.40, $p = 0.011$), single-living (OR 1.66, $p < 0.001$), being female (OR 1.53, $p < 0.001$), living in an urban area (OR 1.42, $p < 0.001$), and some degree of education (OR 1.23, $p < 0.001$). In contrast, the results of the descriptive analysis demonstrated that greater education or equal to high school level was associated with a higher mortality due to dementia (OR 1.23, $p = 0.001$), similarly, living in an area with a population > 500 thousand people was associated with higher mortality (OR 1.23, $p = 0.001$). Medical care

affiliation and having entitlement were not associated with mortality due to dementia. Living in an area with < 500,000 people (OR 0.75, $p < 0.001$), a level of education less than high school (OR 0.81, $p = 0.001$), speaking an indigenous language (OR 0.741, $p < 0.001$), living in a rural area (OR 0.70, $p < 0.001$), male gender (OR 0.65, $p < 0.001$), and age between 65 and 79 years (OR 30, $p < 0.001$) were associated with lower mortality risk due to dementia having an occupation or not was not associated with greater mortality due to dementia.

Discussion

In this study, different sociodemographic characteristics were observed to be associated with mortality due to dementia in the Mexican population aged 65 and above during the years 2012-2016. According to a

Table 2. Logistic regression model

Variable	OR	p < 0.05
Population > 500 thousand	1.33	< 0.001
Population < 500 thousand	0.75	< 0.001
Age	1.07	< 0.001
Economically active	0.95	0.355
Not economically active	1.05	0.355
Education	1.23	< 0.001
< High school	0.81	0.001
≥ High school	1.23	0.001
With partner	0.60	< 0.001
Without partner	1.66	< 0.001
Medical care	1.06	0.308
Insurance	0.98	0.695
Urban area	1.42	< 0.001
Rural area	0.70	< 0.001
Indigenous ethnicity	0.74	< 0.001
Male	0.65	< 0.001
Female	1.53	< 0.001
65-79 years	0.33	< 0.001
80-99 years	2.91	< 0.001
>100 years	1.40	0.011

OR: odds ratio.

meta-analysis of 157 epidemiological studies carried out between 1980 and 2009 around the world, the prevalence of dementia, depending on the geographical zone, lies between 5 and 8% of adults older than 60 years. Moreover, a pattern of exponential growth in the number of dementia cases is observed with increasing age, approximately doubling every 5 years, and predominates among females¹.

In our study, the age range that was associated with greater mortality was 80-99 years (OR 2.91, $p < 0.001$). The proportion of the population characterized by extreme old age is growing rapidly. According to Kravitz et al., the presence of dementia in this group is estimated between 50 and 60%, probably due to the accumulation of preventable risk factors associated with increased age¹³. In general, age is a risk factor for the development of cognitive and physical pathologies and compromises individual function; in the extremely old

population, this is accentuated and they are affected by multiple morbidities or at least two chronic degenerative illnesses¹⁴.

The most frequently occurring pathologies in this age group include depression, frailty syndrome, osteoporosis, diabetes, osteoarthritis, chronic renal disease, cancer, and cardiovascular diseases; dementia can contribute to the poor treatment of these comorbidities, leading to a fatal outcome^{14,15}.

The prevalence of sensory changes in this population increases considerably, in adults older than 85 years it is estimated that the prevalence of auditory deficiency is approximately 70-90% and visual deficiency is 23%, a diagnosis of dementia could potentially cause an increase in mortality within this group¹⁶.

Similar results, with respect to mortality in this aged population, can be observed in a cohort study conducted by Martín et al. It was found that an age > 84 years was a predictor of mortality in a Spanish population of 75 years or older hospitalized with dementia ($n = 195$)¹⁵. It can be inferred that dementia increases the risk of complications associated with the general characteristics of the extreme old age group, limiting their ability to self-care, increasing the likelihood of institutionalization, and hospitalization; in addition to, complications associated with chronic degenerative diseases, which could increase mortality.

Being a woman was strongly associated with mortality due to dementia with an OR of 1.53 ($p < 0.001$). In comparison, male gender was observed to be protective in this population (OR 0.65, $p < 0.001$). Conversely, Garcia-Ptacek et al. conducted a study in a Swedish population and reported that male sex is associated with greater mortality due to dementia¹⁶. The results obtained in the present study can be attributed to the greater life expectancy of women within the Mexican population, which is associated with other risk factors of mortality due to dementia such as reaching older age and living alone without a partner¹⁶.

In relation to the socioeconomic level, Van de Vorst et al. conducted a cohort study of 15,558 participants during the years 2000-2010, the main result obtained indicated that a lower socioeconomic level is associated with greater risk of death in both men and women with dementia¹⁷. In contrast to previously reported studies, low income was not associated with odds of mortality related dementia. In the present study, dementia-related mortality was mainly linked to otherwise favorable sociodemographic characteristics, whereby a higher socioeconomic level increased the probability of dementia-related deaths.

Interestingly, it was observed that having a level of education greater than high school was associated with higher mortality compared to a lower education level (OR 1.23 vs. 0.83 $p = 0.001$). Contador et al. conducted a study on a sample of Spanish patients diagnosed with dementia ($n = 306$) and observed that a more rapid decline in cognition was associated with greater academic achievement. Subsequently, Contador et al. conducted a cohort study of the Spanish population living with dementia ($n = 269$) and found a direct relationship between the level of education and mortality due to dementia¹⁸. This association between the level of education and mortality due to dementia could be related to the ability to carry out a greater number of complex tasks; when a clinical diagnosis has been established, it is assumed that the patient with greater academic attainment can directly perceive the impact of the spectrum of symptoms on their daily activities, such as increasing frailty, depression, and among other geriatric symptoms, which increases the probability of a fatal outcome. In light of this observation, there exist only a few studies that address this association, yet it is necessary to establish causality.

The association between the development of dementia and being single (without partner), has been addressed in multiple articles; for instance, in a systematic review and meta-analysis of 15 observation studies with a total of 812,047 participants, Sommerlad et al. (2018) observed that single participants and widowers had a relatively greater risk of developing dementia in comparison with married couples (with partner)¹⁹. Many studies have consistently demonstrated higher mortality in elderly persons living without a partner that has a diagnosis of dementia. The results of this study demonstrate that being single is associated with higher mortality (OR 1.66 vs. 0.6, $p < 0.001$); in addition, Lewis et al. observed similar results in a British population ($n = 4684$), with an increased risk of mortality in this population group. In contrast, there is evidence that in the general population couples (with partner) live longer⁸. Among possible explanations for this increase in mortality, it is plausible that social support is better with a partner than without since couples tend to share healthy habits and are more likely to use health support services. Likewise, frequent social interaction could contribute to a slower progression of dementia-related symptoms⁸. The family also has an extremely important role as primary caregivers of the person with dementia; according to Kourakos (2016) et al., the family environment may delay the onset of symptoms and the need for a professional caregiver^{14,19}.

The present study also identified an effect of the person with dementia inhabiting either rural or urban

zones, it was observed that those individuals living in an urban zone (OR 1.42, $p < 0.001$) and within a population $> 500,000$ inhabitants (OR 1.33, $p < 0.001$) exhibited higher rates of mortality due to dementia compared to those living in rural zones (OR 0.7, $p < 0.001$) and within a population $< 500,000$ inhabitants (OR 0.75, $p < 0.001$). In another study conducted on the population of the Republic of Congo in adults older than 65 years diagnosed with dementia ($n = 2000$), it was found that living in an urban zone is strongly associated with mortality due to dementia²⁰. It has been observed that social support and health care differ between urban and rural zones; for instance, in a longitudinal cohort study of a Swedish population, Roheger et al. (2018) assessed mortality of patients with dementia that reside in nursing homes and observed that those that live in urban zones were more likely to be hospitalized at the time of diagnosis. However, no difference in mortality was identified²¹.

The identification of sociodemographic factors that increase mortality in older adult populations living with dementia is important within context, as reported by Gutiérrez et al. At present, in Mexico, there are more than 13 million adults older than 60 years experiencing their quality of life and independence being threatened by disability which is secondary to dementia²². According to the results of the dementia investigation group of Alzheimer's disease international 10/66, the incidence of this pathology in Mexico was 16.9/1000 people/year in an urban region and 34.2/1000 people/year within a rural region, these high figures will continue to rise due to the epidemiological transition that the country is experiencing, it is estimated that there will be 3.5 million affected by dementia by 2050.

In Mexico, the cost of caring for a person with dementia has risen to a total of 6157 dollars per capita²³. Dementia is an undervalued pathology since it can increase the morbidity and mortality of other pathologies present before diagnosis. Considering the economic impact, disability, progressive deterioration, the impact on caregivers and the family; in addition to contributing to an increase in mortality in the elderly population, it is mandatory to establish prevention strategies, a plan of action, with public health policies focused on the reduction of modifiable factors that increase the incidence and mortality due to dementia²³.

In this study, the mortality due to dementia was found to be mainly associated with women between 80 and 99 years, inhabiting an urban zone with a population of more than 500,000 inhabitants, being educated beyond high school level and living alone without a partner.

These results suggest that the mortality due to dementia in Mexico is partly a cosmopolitan phenomenon, associated with otherwise favourable socioeconomic conditions and, with this, guides the implementation of strategies that not only permit a longer life expectancy but also a higher quality of life, free of the manifestations of dementia.

As any other study, the present one has certain limitations that need to be considered. All of the information used in this article was obtained from the national mortality registry, which is based on the information contained in death certificates (available from INEGI) that might not be always completed by a medical practitioner. The basic cause of mortality in all cases that were included for the purposes of the present study was dementia; nevertheless, there is a possibility that if dementia was not correctly diagnosed (as when the death certificate was not elaborated by a medical doctor) as the basic cause of death, patients' basic cause of death might have been mistaken with the direct cause of death which could include death by respiratory tract infections or aspiration due to swallowing impairment derived from dementia.

Conflicts of interest

None.

Funding

None.

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Sensory profile in children with autism disorder and children with typical development

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Abstract

Objective: The objective of the study was to compare the sensory profile characteristics of the children with autism spectrum disorder (ASD) and children with typical development (TD) within the ages of 3 and 12 years who attended the rehabilitation center in Barranquilla and Valledupar Colombia. **Methods:** A study of descriptive type correlation of the sensory profile was conducting using the Short Sensory Profile 2 by Winnie Dunn on boys and girls with an ASD diagnosis and children with a TD. **Results:** A total of 59 test subjects were included in the study comprised 39 children on the ASD (5 girls and 36 boys) and 28 children with a TD (11 girls and 17 boys). The medium age was 6.97 for the ASD group and 6.61 for the TD group. There are differences in each of the patterns of pre-processing and sensory systems analyzed in children on the ASD and TD ($p < 0.05$) except at the visual system processing level ($p > 0.05$). **Conclusions:** The study indicates that there is a significant difference in between the ASD group and the TD group, these differences indicate that the population with ASD presents higher level in regard to sensory processing patterns in comparison to TD in accordance to each category in the Short Sensory Profile 2 by Winnie Dunn.

Key words: Sensory profile. Autism spectrum child. Neurotypical. Child.

Introduction

The American Psychiatric Association with acronyms APA¹ published in 2013, the Diagnostic Manual of Mental Disorders DSM-5 where the Asperger, unspecified developmental disorders, and autism were united in a single diagnostic criterion called autism spectrum disorder (ASD). In this neurodevelopmental disorder, there is a deficit in communication, socialization and the interaction of multiple contexts, as well as restrictive, repetitive patterns of behavior, and restrictions of interest or activities². The prevalence of ASD worldwide is approximately 1-6 per thousand individuals. In the

United States, it is one to every 59 individuals. In Colombia, there are no exact data at present³.

Approximately, between 45% and 96% of children with ASD⁴ and 11 and 16% of children with typical development (TD) have sensory processing deficits⁵, however, in Latin American children, it is between 18 and 31%⁶. This type of alterations was initially defined by Ayres as a sensory integration disorder that consists of an alteration of the functioning of the nervous system due to the fact that the information received through the different senses is not processed adequately and efficiently^{7,8}. Giving some kind of sensory integrative dysfunction such as motor restlessness, inadequate

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Date of reception: 07-01-2019

Date of acceptance: 27-03-2019

DOI: 10.24875/RMN.M19000019

Available online: 30-10-2019

Rev Mex Neuroci. 2019;20(5):229-236

www.revexneurociencia.com

coordination, problems of visual perception, and difficulties in following the rhythm of work in class and others^{9,10}.

Subsequently, Miller et al.¹¹ proposed the term sensory processing disorder, referring to those individuals who experienced difficulties in the participation of activities of daily life, as a result of alterations in sensory processing. This proposal is divided into three categories: sensory modulation disorder, sensory-based motor disorder, and sensory discrimination disorder. In 1997, Dunn¹² proposes a new approach in which she poses four patterns of sensory processing that arise from the interaction between the types of thresholds (high or low) and the type of response (agree or against).

Within the patterns of sensory integration is the pattern of low registration, corresponding to the responses of high neurological threshold and a tendency to act passively. That is, the individual within this pattern fails to perceive the same intensity of information of the environment and does not seem any need to satisfy his response (passive). One example of these behaviors is not realize that his face or hands are dirty, leave clothes twisted after going to the bathroom or difficulty to determine the amount of force they should use when doing sports or during fine motor activities^{12,13}.

In the search pattern, there are responses against the high neurological threshold, children with this type of pattern require a great intensity of sensory information, which they do not receive from the daily stimuli of their environment, leading them to acquire an active role to counteract its threshold^{13,14}. The behaviors of a child with a search pattern correspond precisely to those of a child who presents search for sensations, an example of these behaviors are: the continuous search for movements, seems to be unaware of the danger; constantly looking for or making noise, squeezing objects, touching or embracing others excessively and taking inedible objects to the mouth¹⁴.

Regarding the sensitivity pattern, children are able to perceive sensations despite the fact that they involve a small amount or intensity of information, becoming simply a kind of "radar" when detecting information, but they do not acquire an active role to counteract its threshold, an example that clearly describes this pattern is the distraction that occurs in noisy environments^{13,14}. Finally, there is the sensory seeker, this pattern is characterized by presenting a high sensory threshold but employs strategies of active self-regulation, that is, individuals seek and crave sensory stimulation in an unusual way, showing an insatiable desire to increase the intensity of the stimulus^{13,14}.

According to the model proposed by Winnie Dunn, this allowed him to design the sensorial profile questionnaire; the internal consistency level of the instrument is 0.97 Cronbach's Alpha and presents versions in English, Spanish, and Chinese. The application time of the instrument is approximately 45 min; this questionnaire must be applied by the occupational therapists to the caregivers and nurses of the children or on the contrary observations are made by the professional in charge so that it can be completed¹⁵.

Previous studies have reported that there are multiple mechanisms through which sensory disturbances at an early age in children with ASD enter a cascade of social deficits that affect functionality in this type of population. In the United States, they have identified that 95% of children with ASD present some degree of diffusion in sensory processing, specifically altered sensory systems are often auditory, visual, and tactile^{16,17}. Studies conducted in children with TD have reported a prevalence of sensory processing disorders between 14.3 and 28.6%, which affected their school activities and activities of daily living¹⁸.

The one developed by Mailloux and Miller-Kuhaneck¹⁹ is one of the few studies that have made comparisons of the sensory profile; those that compared the characteristics of sensory processing among a group of children living in the United States (between 5 and 8 years of age) with and without ASD. In this study, 84 children and their parents participated; the results show that both groups behave differently in all the subscales that evaluate the sensory processing, in the case of the group with ASD, the behaviors they present are significantly related to the degree of severity in the symptoms of autism.

The authors agree that the sensory profile evaluations allow a better understanding of the sensory deficit and thus provide the possibility of generating therapeutic measures according to the needs of each individual, due to the heterogeneous characteristics that occur in each child with ASD and DT^{19,20}. So far, most of the research conducted in this area has been in the United States and Europe; however, there is a low level of scientific evidence in South America about the variety of sensory responses that can be presented in the groups to be studied²¹. Despite the high impact that this type of alterations generates on the functional performance of children with ASD and DT, no comparative studies have been reported in Latin America. Obtaining this type of data is essential to identify the differences and similarities that may occur in both groups, in this sense those factors influence the timely detection of sensory alterations, which generate a negative impact on the

Table 1. Interpretation of results from the Winnie Dunn categories.

Sensory processing patterns	Less than other/much less than others	Just like the majority of others	More than others/much more than others
Seeking	May not look for enough sensory information to sustain successful participation	Use sensory stimuli to gather the information necessary for their participation	Can search for sensory information so excessively or disruptively that it interferes with participation
Avoiding	The detection of the sensory stimulus necessary for participation may fail	Handles sensory information to get only the amount needed for participation	Can become so overwhelmed by sensory information that it interferes with participation
Sensitivity	May not detect the sensory input particularly necessary to sustain participation	Detects the sensory input that allows participation	Maybe so distracted by sensory information that it interferes with participation
Registration	Can observe sensory stimuli that are not useful for participation	Observes enough sensory stimuli that allow participation	May lose the sensory information necessary for participation

Reference source: sensory profile Winnie Dunn

performance of school activities and of daily life in both groups. Therefore, it is considered necessary to analyze the impact of this type of deficit in age groups or development status because it directly affects an effective intervention. The main objective of this study was to determine and compare the sensory profile in a sample of children between 3 and 12 with ASD and TD through the Sensory Profile of Winnie Dunn.

Methods

A transversal descriptive study of correlation type was carried out where 59 participants were selected through a non-probabilistic sampling for convenience, in this case, 28 children with TD and 31 children with ASD met the following inclusion criteria; boys and girls between the ages of 3 and 12 years, with diagnosis confirmed by a neuropsychiatric of ASD, in the case of children with TD they should not have presented any warning sign during their psychomotor development; for both groups of participants the parents had to sign the informed consent.

Materials

To fulfill the objective of the research, the sensory profile of Winnie Dunn Spanish version was applied to 59 participants, this questionnaire is divided into three sections that evaluate; the sensory system (visual, auditory, oral, proprioceptive, and vestibular) together with the sensory patterns (Search, avoidance, low register, and sensitivity) and behavior (behavior, attention, and social emotions). It contains 125 questions related to the sensory aspect and has as options of answers: almost

always (5), frequently (4), half of the time (3), occasionally (2), almost never (1), and not applicable (0), for the qualification, the sum of the answers to each question was made according to the evaluated item, later this score is compared with the scales that go according to each item and that in this case indicates the categories that the child is in; less than other/much less than others, just like the majority of other and much more than/more than other, each of the above presented an interpretation that indicated the sensory characteristics presented by children with ASD and DT evaluated (Table 1).

Process

The researchers conducted a review of the literature based mainly on the theory described by the Occupational Therapists Jean Ayres and Winnie Dunn, analyzing the sensory behaviors within the areas of action in which individuals develop sensory level.

Subsequently, the evaluators went to the educational institutions and rehabilitation centers located between the cities of Barranquilla and Valledupar, where the risks, procedures, and benefits of the investigation were shared with parents, managers, therapists, caregivers, and teachers. The informed consent form was given to the parents who accepted their children's participation in the study. Data collection by occupational therapists was carried out during the months of June and July of 2018, through the technique of direct observation and interviews with parents, the evaluators were trained to perform the registration of the Winnie Dunn format. In addition, the professionals in charge of the evaluation have 6 years of experience in the assessment and intervention of this population.

As part of the evaluations carried out, each therapist performed the respective screening according to the sensory behaviors reported in the instrument; finally, the information collected was entered into a database designed in Excel version 2010 and was later exported to the statistical software SPSS version 20.

Statistic analysis

According to the information collected, an analysis of the proportional distribution of the following variables was carried out; sociodemographic characteristics, sensory processing patterns, processing, and behavior system; later to identify whether the variables of the sensory profile were parametric or non-parametric, the Kolmogorov–Smirnov statistical test was applied in both groups (DT-TEA); finally, to establish the differences and similarities of both groups about the sensory profiles, the student's t-test for independent samples was applied, accepting a significant value of $p < 0.05$.

Results

At the level of sociodemographic characteristics, the following was observed; there is a greater number of male participants in both the ASD group and DT group, 64.5% of the ASD group and 100% of the group with TD are in school, the average age of the ASD participant is 6.97 ± 2.93 and in children with TD was 6.61 ± 3.29 (Table 2).

Regarding the patterns of sensory processing evaluated through the sensory profile of Winnie Dunn, in the search pattern, it was observed that 45.2% of the group with ASD is within the response category more than other/much more than other. It means that children with ASD can search for sensory information so much that it interferes with participation, while 64.3% of the group with DT is in the category just like majority than others, which means that they use various sensory stimuli to gather the information necessary for active participation (Table 3).

Regarding the pattern of avoidance, it is confirmed that 54.8% of children with ASD are within the score more than other/much more than other, which indicates that they can be overwhelmed with sensory information to such an extent that interferes with their participation. As for children with TD, 60, 7% are in the category of just like the majority of others (Table 3).

In the sensitivity pattern within the obtained results it was evidenced that 64.5% of the group with ASD are within the score more than other/much more than other which indicates that they can be distracted with both the non-organized sensory information. On the other

Table 2. Sociodemographic characteristics of the groups studied.

Sociodemographic characteristics	Frequency (%)	
	ASD	DT
Gender		
Female	5 (16.1)	11 (39.3)
Male	26 (83.9)	17 (60.7)
Schooled		
Yes	20 (64.5)	28 (100)
No	11 (35.5)	0

Reference source: sensory profile Winnie Dunn. ASD: autism spectrum disorder; DT: typical development

hand, 89.3% of the children with DT are in the “just like the majority of others” category, that is, they detect the sensory stimuli that allow their participation.

In the registration pattern, both the group with ASD and that of DT were rated within the category just like the majority of others, it means, they perceive the amount of stimuli sufficient for correct participation. The results and the comparisons revealed that there are significant differences between the group with ASD and the group with DT ($p = 0.00$) (Table 3). In each of the evaluated patterns, the TEA group shows a trend of higher values (41.77 ± 18.72) compared to the measurement of the DT group (24.500 ± 8.87) (Table 4).

At the level of auditory sensory processing systems, 74.2% of children with ASD and 64.3% of children with TD are within the response category just like the majority of others, in sensory processing visual 48.4% of the group with ASD and 42.9% of children with TD are in the category just like the majority of others. However, 53.5% of children with TD and 38.7% of ASD are in the less than other/much less than other category, which indicates that they are below the response threshold established by Dunn. In tactile sensory processing, 51.7% of children with ASD are in the more than other/much more than other category, with this high threshold giving rise to determining that there is greater tactile defensibility that bursts into their behavior, whereas the group with DT 67.9% of children is in the category just like the majority than other (Table 5). Otherwise, in both groups, both TEA and DT are in the category just like the majority than other at the level of the vestibular, proprioceptive, and gustatory systems. Regarding the sensory processing systems evaluated through the Winnie Dunn sensory profile, the results and comparisons revealed that there are significant differences between the group with ASD and the group with DT in each of the systems ($p = 0.00$) except in the visual system ($p = 0.31$) (Table 6).

Table 3. Mean difference in sensory processing patterns

Patterns of sensory processing	Groups	Media (SD)	Differences of medias	p
Seeking	ASD	42.290 ± 19.03	13.32	0.00*
	DT	28.964 ± 4.41		
Avoiding	ASD	48.77 ± 16.71	19.45	0.00*
	DT	29.321 ± 14.48		
Sensitivity	ASD	45.806 ± 15.21	17.09	0.00*
	DT	28.714 ± 9.24		
Observation	ASD	41.774 ± 18.62	17.27	0.00*
	DT	24.500 ± 8.87		
Auditory	ASD	19.387 ± 6.95	5.78	0.00*
	DT	13.607 ± 6.78		
Visual	ASD	10.25 ± 6.11	1.4	0.31
	DT	8.857 ± 4.24		
Touch	ASD	22.419 ± 9.99	6.91	0.00*
	DT	15.500 ± 7.54		
Movement	ASD	17.613 ± 8.88	6.75	0.00*
	DT	10.857 ± 5.83		
Body position	ASD	12.516 ± 9.09	5.69	0.00*
	DT	6.812 ± 5.60		
Oral	ASD	20.065 ± 9.68	5.38	0.02*
	DT	14.679 ± 8.16		
Behavioral	ASD	22.387 ± 9.14	7.99	0.00*
	DT	14.393 ± 6.59		
Socioemotional	ASD	34.613 ± 14.7	13.68	0.00*
	DT	20.929 ± 13.85		
Attention	ASD	29.903 ± 10.39	14.54	0.00*
	DT	15.357 ± 7.09		

Reference source: sensory profile de Winnie Dunn. *p < 0.05 Significant differences. ASD: autism spectrum disorder; DT: typical development; SD: standard deviation.

Regarding the proportional distribution measures, it was identified that at the behavioral level, 51.7% of children with ASD are in the category more than other/much more than others, this occurs in the same way in the items of attention and socioemotional relationships, giving rise to the responses or sensory challenges directly affect the performance in the activities of daily life, generating behaviors that are misinterpreted as not very adaptive. However, the group with DT is within the response category just like the majority of others, that is, sensory processing systems may not affect the behavior of this population

(Table 5). Both groups present significant differences in each of the variables ($p = 0.00$), the group with ASD has a tendency to score above the mean at the behavioral level (22.387 ± 9.14), socioemotional relationships (34.613 ± 14.7), and attention (29.903 ± 10.39) with respect to the group of children with TD (Table 4).

Discussion

Based on the results obtained in this research, we identified within the sociodemographic characteristics

Table 4. Percentage distribution of the processing patterns of the groups studied

Patterns of sensory processing	Frequency (%)	
	ASD	DT
Seeking		
More than other/much more than other	14 (45.2)	3 (10.7)
Less than other/much less than other	4 (12.9)	7 (25)
Just like the majority than others	13 (41.9)	18 (64.3)
Avoiding		
More than other/much more than other	17 (54.8)	4 (14.3)
Less than other/much less than other	0	7 (25)
Just like the majority than others	14 (45.2)	17 (60.7)
Sensitivity		
More than other/much more than other	20 (64.5)	1 (3.6)
Less than other/much less than other	2 (6.5)	2 (7.1)
Just like the majority than others	9 (29)	25 (89.3)
Registration		
More than other/much more than other	12 (38.7)	5 (17.9)
Less than other/much less than other	2 (6.5)	0
Just like the majority than others	17 (54.8)	23 (82.1)

Reference source: sensory profile Winnie Dunn. ASD: autism spectrum disorder; DT: typical development.

that the majority of the population with ASD evaluated is male, with an average age of 6 years; they are in school and with therapeutic intervention. These data coincide with that reported by the Centers for Disease Control of Atlanta with acronyms CDC³ where it states that one in every 59 children between the ages of 6 and 8 years have been diagnosed with ASD with a 4 times higher tendency in man than in women, likewise, 95% of children diagnosed with ASD resident in the United States have been included in special education programs.

At the level of sensory processing patterns, we observed that both groups behave differently in the patterns of search, avoidance, sensitivity, and observation. The group with ASD presented alterations in the aforementioned patterns compared to the group with DT, which presented a performance according to age and condition in each of them, these results coincide with the reported by Brown et al.²², who in the same way compared a group with ASD and a group with DT and found that there were significant differences in those patterns ($p \leq 0.017$), the group with ASD showed alterations in sensory processing. Similar results were reported in the study conducted by Brockevelt, et al.²³ In the United States in a sample of 21 children with ASD between the ages of 3 and 9 years, also reported that there are significant differences between the groups with ASD and DT in each of the sensory patterns ($p < 0.001$). Little et al.²⁴ presented several studies

Table 5. Percentage distribution of the sensory processing systems of the groups

Sensorial processing system	Frequency (%)	
	ASD	DT
Auditory processing		
More than other/much more than other	6 (19.4)	10 (35.7)
Less than other/much less than other	2 (6.5)	0
Just like the majority than other	23 (74.2)	18 (64.3)
Visual processing		
More than other/much more than other	4 (12.9)	1 (3.6)
Less than other/much less than other	12 (38.7)	15 (53.5)
Just Like the majority than other	15 (48.4)	12 (42.9)
Touch processing		
More than other/much more than other	16 (51.7)	6 (21.4)
Less than other/much less than other	1 (3.2)	3 (10.7)
Just like the majority than other	14 (45.2)	19 (67.9)
Vestibular processing		
More than other/much more than other	14 (45.1)	3 (10.7)
Less than other/much less than other	2 (6.4)	5 (17.9)
Just like the majority than other	15 (48.4)	20 (71.4)
Proprioceptive processing		
More than other/much more than other	9 (29)	1 (3.6)
Less than other/much less than other	6 (19.4)	8 (28.6)
Just like the majority than other	16 (51.6)	19 (67.9)
Gustatory processing		
More than other/much more than other	11 (35.5)	2 (7.1)
Less than other/much less than other	1 (3.2)	4 (14.3)
Just like the majority than other	19 (61.3)	22 (78.6)

Reference source: sensory profile Winnie Dunn. ASD: autism spectrum disorder; DT: typical development.

Table 6. Percentage distribution of behavior of the groups studied

Behavior	Frequency (%)	
	ASD	DT
More than other/much more than other	16 (51.7)	1 (3.6)
Less than other/much less than other	1 (3.2)	5 (17.9)
Just like the majority than other	14 (45.2)	22 (78.6)
Socialemotional relationship		
More than other/much more than other	17 (54.8)	5 (17.9)
Less than other/much less than other	1 (3.2)	6 (21.4)
Just like the majority than other	13 (41.9)	17 (60.7)
Attention		
More than other/much more than other	21 (67.8)	2 (7.1)
Less than other/much less than other	1 (3.2)	4 (14.3)
Just like the majority than other	9 (29)	22 (78.6)

Reference source: sensory profile Winne Dunn. ASD: autism spectrum disorder; DT: typical development.

under the same approach, which state that the sensory patterns of the groups studied are different.

Likewise, the group with ASD presented higher scores with respect to the DT group at the level of the

patterns and sensory processing system; each of the groups presented significant differences. Those results coincide with the study carried out by Linde et al.²⁵, in the USA that affirms that the scores of the ASD are always superior in each of the patterns of sensory processing with respect to the DT. However, in the study conducted by Brown et al.²² and Brockevelt et al.²³ found that the group diagnosed with ASD residing in Australia and another group of children with the same condition residing in the United States had significantly lower scores in comparing the group of children with TD in each of the sensory processing patterns, the sensory patterns were altered in all the groups studied with ASD.

The study conducted by Tomchek and Dunn²⁶ in the USA with a sample of 281 children with and without ASD, partially supports the results obtained, stating that both groups had significant differences in each of the systems (visual, auditory, tactile, gustatory, vestibular, and proprioceptive) ($p = 0.00$). Cervera et al.²⁷ also performed a study in a sample of children with ASD and DT in Spain, in this case, they reported that statistical comparisons revealed significant differences between both groups ($p = 0.00$).

Regarding the level of the auditory sensory processing system, both the group with ASD and the group with DT, register a threshold within the typical sensory parameters, that is, their performance is in accordance with the chronological age, those results are contrary to the exposed by Tomchek and Dunn²⁶ where 77.6% of children with ASD present alterations in this system and 87.8% of children with SD have a performance within the range. Similarly, in Canada, in a study conducted by Nadon et al.²⁸, I observed that 55.8% of children with ASD presented alterations of the auditory type that affect their daily functioning.

In the visual system, DT children presented a low response threshold compared to children with ASD. The last thing coincides with the study carried out by Nadon et al.²⁸ and Tomchek and Dunn²⁶. Where children with ASD present a typical performance score and children with SD were below the scores established by the Winnie Dunn scale.

In relation to the tactile system, the majority of the group with ASD tended to have a high response threshold in proportion to the group with DT that presented a performance within the typical range. This coincides with the study carried out by Linde et al.²⁵, which reports that 60.1% of children with ASD present alterations in this system.

In the gustatory system, the majority of children with ASD had a higher response threshold compared to children with DT who presented a performance according to age. These results are related to the study developed by Dunn¹² and Al-Heizan et al.²⁹ where they also reported deficiencies in this system, specifically 54.1% of children with ASD evaluated, parents reported the intake of only some foods, in the case of children with DT their food intake was wider. In relation to the behavioral item, it was identified that the majority of the group with ASD reflect poorly adapted behaviors as consequences of faults in patterns and sensory systems. This coincides with the study carried out by Cervera et al.²⁷ and Little et al.²⁴ it was identified that the majority of the group with ASD presents alterations at the level of social participation due to deficiencies in the sensory system, children with DT show adaptive responses according to the expected performance for their age.

Conclusions

From this study, we can infer that there are differences between the sensory profiles of the compared groups as they were DT and ASD, in addition, the sensory deficit prevalence is higher in ASD than in children with TD. In this case, it is of vital importance the intervention of these deficiencies through sensory integration programs that allow a foster adaptive response by children with ASD. It is necessary that this type of sensory modulation be provided at home, school, and in the therapeutic environment for each one of the professionals in charge of the intervention in this type of population.

Despite the limitations that some professionals have to certify themselves as sensory integrators, we believe that this work is a first step to examine in a sample of Colombian children with and without ASD dysfunctions in sensory integration, and therefore raise awareness about the different difficulties that this group usually faces.

Ethical disclosures

Protection of people and animals. The authors declare that the procedures followed to conform to the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

Confidentiality of the data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

Conflicts of interest

The authors declare that there are no relevant conflicts of interest.

Funding

The particular sources of financing for this scientific report was Foundart Academy Headquarters, Miami, United States.

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Descriptive epidemiology of intracranial hemorrhage patterns and the main complaints motivating brain computed tomography scans in Northern Portugal

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Abstract

Background/Aims: This study aimed at documenting the patterns of intracranial hemorrhage encountered by means of brain computed tomography (CT) scan and characterizing the chief complaint that led to the diagnosis. **Methods:** All the brain CT scans performed in a hospital serving 334,081 inhabitants in a 1-year period were reviewed. Categories of clinical situations and imaging findings were correlated among themselves and with population data to obtain incidence rates. **Results:** A total of 8516 patients (M/F ratio 0.83; mean age 63.31) underwent brain CT scans and hemorrhage was present in 448 (5.26%). Head injury was the most frequent complaint motivating brain CT scan (30.11%) and acute subdural hemorrhage the most frequent pattern encountered (37.05%). An incidence rate of intracranial hemorrhage of 134.10, a global incidence rate of head injury of 767.48, and an incidence rate of hemorrhage of 76.33/100,000/year in the context of trauma were found. Incidence rates of hemorrhagic patterns more likely to be associated with a spontaneous origin add up to 45.2/100,000/year. **Conclusion:** Traumatic patterns of hemorrhage are more frequent than those of spontaneous nature and head injury the most frequent indication for brain CT scan study. Although within the ranges reported in literature, incidence rates of hemorrhage in the studied population rank low for trauma and spontaneous subarachnoid and high for intracerebral. This indicator serves to characterize the health status of the community.

Key words: Incidence. Head injury. Intracerebral hemorrhage. Spontaneous subarachnoid hemorrhage. Portugal.

Epidemiología descriptiva de los patrones de hemorragia intracraneal y de las quejas principales motivadoras de TAC cerebral en el Norte de Portugal

Resumen

Antecedentes/Objetivos: Este estudio tuvo como objetivo documentar los patrones de hemorragia intracraneal encontrados mediante tomografía computarizada cerebral y caracterizar la queja principal que condujo al diagnóstico. **Métodos:** se revisaron todas las tomografías cerebrales realizadas en un hospital que atendía a 334,081 habitantes en un periodo de un año. Las categorías de situaciones clínicas y los hallazgos de imagen se correlacionaron entre sí y con los datos de población

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Date of reception: 13-06-2018

Date of acceptance: 23-11-2018

DOI: 10.24875/RMN.M19000070

Available online: 30-10-2019

Rev Mex Neuroci. 2019;20(5):237-243

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para obtener tasas de incidencia. **Resultados:** 8.516 pacientes (relación M/F 0.83; edad media 63.31) se sometieron a tomografías computarizadas cerebrales y existía hemorragia en 448 (5.26%). Traumatismo craneal fue la queja más frecuente que motivó la TC cerebral (30.11%) y la hemorragia subdural aguda el patrón más frecuente encontrado (37.05%). Se encontró una tasa de incidencia de hemorragia intracraneal de 134.10, una tasa de incidencia global de traumatismo craneal de 767.48 y una tasa de incidencia de hemorragia de 76.33 por 100,000 por año en el contexto de trauma. Las tasas de incidencia de patrones hemorrágicos más propensos a asociarse con un origen espontáneo suman 45.2 por 100,000 por año. **Conclusión:** Los patrones traumáticos de hemorragia son más frecuentes que los de naturaleza espontánea, y el traumatismo craneal es la indicación más frecuente para el estudio de tomografía computarizada cerebral. Aunque dentro de los rangos reportados en la literatura, las tasas de incidencia de hemorragia en la población estudiada son bajas para traumatismo y subaracnoidea espontánea, y altas para intracerebral. Este indicador sirve para caracterizar el estado de salud de la comunidad.

Palabras clave: Incidencia. Traumatismo craneal. Hemorragia intracerebral. Hemorragia subaracnoidea espontánea. Portugal.

Introduction

It is of common medical knowledge that the incidence of intracranial hemorrhage of traumatic and spontaneous origins is dependent on multiple variables such as, and among others, access to medication and medical care, lifestyle, genetic predisposition, traffic hazards, work security conditions, and crime issues. Despite the difficulty in calculating the weight that each variable may have in the incidence of intracranial hemorrhage, this indicator can serve to characterize the health status of a community. Computed tomography (CT) scan is the most widely used method for diagnosing intracranial hemorrhage and its efficacy is well defined. At present, available software used for viewing and archiving medical imaging, as well as reports, allows for easy access to all the examinations performed in a certain period of time and to the diagnoses made. The aim of this study was to document the patterns of intracranial hemorrhage encountered by means of brain CT scan in a large urban community in Northern Portugal, and further characterize the chief complaint that led to the diagnosis, providing ciphers in the perspective of descriptive epidemiology that are not readily available. Monitoring the incidence of pathologies that can have devastating neurological outcomes such as head injury and hemorrhagic stroke is of uttermost relevance; if rates encountered compare unfavorably to those of others, study and adoption of efficacious measures aimed at the prevention of these disorders and events should lead to their decrease and to consequent improvements in the health status of the community.

Methods

The population studied had access to one public hospital with a neurological and neurosurgical unit that

had recently started to cover emergency cases. On the one hand, this obviated the need to transfer patients from the hospital to referral institutions as well as direct referral to those institutions from the street. On the other hand, the catchment area was well defined since at that initial time, the hospital aimed only at its direct catchment area, and hospitals from the potential indirect catchment area continued to refer patients to previously established referral institutions. A population census had been performed in the year before the study period that provided an accurate figure of 334,081 inhabitants in the direct catchment area of the hospital (two municipalities)¹. Private facilities available in the area did not, in general, assume surgical cases or complex inpatients, referring them to the public hospital. It was assumed that patients living in other locations that were diagnosed and treated in the hospital (“passers-by”) would compensate for potential patients of the hospital’s direct catchment area treated at outside institutions.

The software used for archiving and viewing of imaging was used to review all the brain CT scans performed in the hospital in a 1-year period (April 2012-March 2013 – Philips Brilliance CT 64 Channel device), along with the summarized clinical information that motivated the examination, the report performed as well as the age and gender of the patients. All the information was obtained from one computer program (Pacs Sectra). Categories used to classify the chief complaint provided by the referring physician were head injury, speech and cognition complaints, headaches, seizures, stupor, syncope, “follow-up,” sensory complaints, motor complaints, post-operative, and “not provided.” If an event of acute trauma was present, this was assumed as the chief complaint, unless it was subsequent to another event such as syncope. If more than one category was present, for example, speech

and motor deficits, the category assumed was the one that the referring clinician mentioned first in the clinical information. Categories used to classify the patterns of intracranial hemorrhage reported by the radiologist were acute subdural and traumatic subarachnoid, epidural, spontaneous cerebral corticosubcortical, spontaneous basal ganglia, spontaneous cerebellar, parenchymal contusion, chronic subdural, ventricular, brainstem, and spontaneous subarachnoid. If more than one category was present, for example, basal ganglia and ventricular, the category assumed was the one that the radiologist described as predominant. If this could not be inferred from the report, the category assumed was the one mentioned first by the radiologist. A volumetric subclassification was not undertaken in this study, meaning that a hemorrhage classified as epidural could range from a minor film to massive. Overlap of categories is well acknowledged as a confounding factor, but these typifications had to be employed given the large size of the sample and the multitude of possible clinical situations and imaging findings. Sorting of data and calculations (including Chi-square analysis/Fisher's exact test with mid-P method/t-test/95% confidence limits score of Wilson) were performed with widely available spreadsheet and statistical analysis software (Microsoft Excel and OpenEpi).

Results

A total of 8516 patients (3855 males, M/F ratio 0.83; mean age in years 63.31; median 67.72; range 0.15–102.30; standard deviation 20.24) underwent 10,884 brain CT scans, implying a global ratio of 1.28 CT scans per patient. This ratio of CT scans per patient deserved further analysis and was viewed in the context of repeat CT scans to follow hemorrhagic pathology previously encountered, as well as new clinical situations affecting the patients, either of the same, or from a different nature. The number of patients that underwent repeat CT scan was indeed 1379 (16.19%), and they underwent 3733 CT scans, implying a corrected ratio of 2.70 per patient in these patients. Hemorrhage was present in the initial CT scan of 303 of the patients that underwent repeat scans (21.97%). Thirty-two initially “unidentified” patients that possibly underwent repeat scans as identified patients could contribute to this figure as well. A uniform criterion to distinguish between repeat CT scans that represented follow-up of known situations versus those that represented concomitant or new clinical situations was not achieved, and

Table 1. Frequencies of chief complaints motivating brain CT scan

Chief complaint	Patients (n)	Percentage/(**)
Head injury	2564	30.11 (29.14-31.09)
Cognition and speech	1273	14.95 (14.21-15.72)
Headache	1260	14.80 (14.06-15.57)
Sensory	909	10.67 (10.04-11.35)
Motor	729	8.56 (7.98-9.17)
Syncope	472	5.54 (5.07-6.04)
Seizures	369	4.33 (3.92-4.78)
Not provided	296	3.48 (3.10-3.88)
Follow-up	286	3.36 (2.99-3.76)
Stupor	280	3.29 (2.93-3.68)
Post-operative	78	0.92 (0.73-1.14)
Total	8516	100.00

**95% Confidence limits score (Wilson). CT: Computed tomography

these subsequent CT scans were excluded from the remaining analysis. It is acknowledged that this may underestimate certain ciphers. The frequency of chief complaints that motivated the first CT scan performed by the patients in the study period is displayed in [table 1](#). Hemorrhage was present in 448 (5.26%) of these initial CT scans. The frequency of hemorrhage per chief indication is detailed in [table 2](#), and Chi-square analysis with $p < 0.05$ supported relevant differences in the proportions found; the frequency of patterns encountered is summarized in [table 3](#). Incidence rates of the diverse situations are shown in [table 4](#). Incidence rates were calculated using as numerator the registered occurrences of clinical situations/imaging findings obtained from the analysis of the CT scans in the 1-year period multiplied by 100,000 and as denominator the 334,081 inhabitants of the direct catchment area of the hospital. Certain age and gender variations according to clinical context and type of hemorrhage are reported in [table 5](#).

Discussion

The methodology employed in the present study for obtaining the cases of intracranial hemorrhage by means of CT scan review allowed for a comprehensive analysis of the phenomenon, in both the traumatic and spontaneous forms. With the exception of the early

Table 2. Frequency of hemorrhage by chief complaint

Chief complaint	Patients without hemorrhage (n)	Patients with hemorrhage (n)	Percentage hemorrhage by complaint/(**)
Head injury	2365	199	7.76 (6.78-8.86)
Cognition and speech	1237	36	2.83 (2.05-3.89)
Headache	1236	24	1.90 (1.28-2.81)
Sensory	899	10	1.10 (0.59-2.01)
Motor	695	34	4.66 (3.35-6.44)
Syncope	461	11	2.33 (1.30-4.12)
Seizures	360	9	2.44 (1.28-4.57)
Not provided	284	12	4.05 (2.33-6.95)
Follow-up	239	47	16.43 (12.59-21.17)
Stupor	249	31	11.07 (7.91-15.29)
Post-operative	43	35	44.87 (34.33-55.89)
	8068	448	

**95% Confidence limits score (Wilson)

Table 3. Predominant type of hemorrhage encountered in brain CT scan

Type of hemorrhage	Patients (n)	Percentage/(**)
Acute subdural	166	37.05 (32.71-41.62)
Cerebellar	10	2.23 (1.21-4.05)
Contusion	72	16.07 (12.96-19.76)
Corticosubcortical	58	12.95 (10.15-16.37)
Chronic subdural	30	6.70 (4.73-9.39)
Epidural	17	3.79 (2.38-5.99)
Basal ganglia	61	13.62 (10.75-17.1)
Spontaneous subarachnoid	18	4.02 (2.55-6.26)
Brainstem	4	0.89 (0.34-2.27)
Ventricular	12	2.68 (1.53-4.62)
Total	448	100.00

**95% Confidence limits score (Wilson)

infancy period in which transfontanelar ultrasonography is many times employed, current practice indicates CT scan as the appropriate examination for diagnosis and follow-up. This approach obviated certain selection bias such as department origin, surgical intervention,

or etiologic (either traumatic or spontaneous cases). Studies employing a selection of cases using codes from the International Classification of Diseases (ICD) or Diagnosis Related Groups (DRGs) may tend to analyze only patients that were categorized as inpatients, i.e. remaining more than 24 h in the hospital. They may not be able to measure the phenomenon of patients that suffer minor head injury and have indeed suffered head injury, but do not have lesions in the CT, and are, therefore, discharged from the emergency room. These patients are users of the health system and resources but may not be accounted for in the head injury statistics. In this study, this can be easily found by looking up head injury indication for CT scan and no intracranial hemorrhage in CT scan result. Another potential pitfall of studies using ICD or DRG codes might have to do with transferred patients. A patient admitted for surveillance in a local hospital who later deteriorates and undergoes surgery in a referral institution, and even later gets transferred again to the local institution, might be counted 3 times for epidemiological purposes with the coding methodology.

In the general characterization of the sociological scenario of the population in study, it would be worth mentioning: relatively easy and affordable access to medical care, as well as antihypertensive, antidyslipidemic, and anticoagulant medication; promotion of physical activity

Table 4. Incidence of clinical situations and imaging findings expressed per 100,000 persons/year and 95% confidence limits mid-P exact test

Chief complaint	No hemorrhage	Acute subdural	Cerebellar	Contusion	Corticospinal	Chronic subdural	Epidural	Basal ganglia	Spontaneous subarachnoid	Brainstem	Ventricular	Total
Head injury	707.91 (679.8-736.9)	36.52 (30.46-43.45)	0.30 (0.01-1.47)	14.67 (10.97-19.23)	0.30 (0.01-1.47)	1.80 (0.72-3.73)	4.19 (2.38-6.86)	0.90 (0.22-2.44)	0.00	0.00	0.90 (0.22-2.44)	767.48 (738.2-797.6)
Cognition and speech	370.27 (350.1-391.3)	0.30 (0.01-1.47)	0.00	0.00	3.89 (2.16-6.48)	1.50 (0.54-3.31)	0.00	4.79 (2.83-7.61)	0.30 (0.01-1.47)	0.00	0.00	381.05 (360.5-402.4)
Headache	369.97 (349.8-391)	0.30 (0.01-1.47)	0.00	0.00	2.39 (1.11-4.54)	0.90 (0.22-2.44)	0.00	0.30 (0.01-1.47)	2.39 (1.11-4.54)	0.00	0.90 (0.22-2.44)	377.15 (356.8-398.4)
Sensory	269.10 (251.9-287.1)	0.30 (0.01-1.47)	0.60 (0.1-1.97)	0.30 (0.01-1.47)	0.30 (0.01-1.47)	0.60 (0.10-1.97)	0.00	0.60 (0.1-1.97)	0.00	0.30 (0.01-1.47)	0.00	272.09 (254.8-290.2)
Motor	208.03 (193-223.9)	0.30 (0.01-1.47)	0.00	0.60 (0.10-1.97)	1.80 (0.72-3.73)	0.30 (0.01-1.47)	0.00	6.59 (4.23-9.80)	0.30 (0.01-1.47)	0.00	0.30 (0.01-1.47)	218.21 (202.8-234.5)
Syncope	137.99 (125.8-151)	1.50 (0.54-3.31)	0.00	0.30 (0.01-1.47)	0.00	0.30 (0.01-1.47)	0.00	0.60 (0.10-1.97)	0.30 (0.01-1.47)	0.30 (0.01-1.47)	0.00	141.28 (129-154.5)
Seizures	107.76 (97.05-119.3)	0.60 (0.10-1.97)	0.00	0.00	1.50 (0.54-3.31)	0.60 (0.10-1.97)	0.00	0.00	0.00	0.00	0.00	110.45 (99.6-122.2)
Not provided	85.01 (75.55-95.34)	0.90 (0.22-2.44)	0.30 (0.01-1.47)	0.30 (0.01-1.47)	0.60 (0.10-1.97)	0.00	0.00	0.60 (0.10-1.97)	0.00	0.30 (0.01-1.47)	0.60 (0.10-1.97)	88.60 (78.93-99.14)
Follow-up	71.54 (62.89-81.05)	5.39 (3.29-8.35)	0.60 (0.10-1.97)	3.29 (1.73-5.72)	1.20 (0.38-2.88)	1.80 (0.72-3.73)	0.30 (0.01-1.47)	0.90 (0.22-2.44)	0.00	0.00	0.60 (0.10-1.97)	85.61 (76.11-95.97)
Stupor	74.53 (65.7-84.23)	2.10 (0.91-4.14)	0.90 (0.22-2.44)	0.60 (0.10-1.97)	0.60 (0.10-1.97)	0.30 (0.01-1.47)	0.30 (0.01-1.47)	2.99 (1.52-5.33)	0.90 (0.22-2.44)	0.30 (0.01-1.47)	0.30 (0.01-1.47)	83.81 (74.42-94.07)
Post-operative	12.87 (9.43-17.18)	1.50 (0.54-3.31)	0.30 (0.01-1.47)	1.50 (0.54-3.31)	4.79 (2.83-7.61)	0.90 (0.22-2.44)	0.30 (0.01-1.47)	0.00	1.20 (0.38-2.88)	0.00	0.00	23.35 (18.58-28.98)
Total	2414.98 (2363-2468)	49.69 (42.55-57.69)	2.99 (1.52-5.33)	21.55 (16.99-26.98)	17.36 (13.3-22.28)	8.98 (6.17-12.66)	5.09 (3.06-7.98)	18.26 (14.09-23.3)	5.39 (3.29-8.35)	1.20 (0.38-2.88)	3.59 (1.94-6.10)	2549.08 (2495-2604)

Table 5. Age and gender variations according to clinical context and type of hemorrhage

Scenario	Total patients	Males	Females	M/F ratio	Mean age (yy)	Median	Min.	Max.	SD
Global	8516	3855	4661	0.83	63.31	67.72	0.15	102.30	20.24
Head injury	2564	1207	1357	0.89	63.72	70.25	0.15	102.30	22.46
Hemorrhage	448	244	204	1.20	66.88	71.74	0.52	97.79	19.22
Head injury with hemorrhage	199	122	77	1.58	65.87	72.92	0.52	97.79	22.22
Basal ganglia	61	39	22	1.77	73.31	74.54	40.61	91.77	11.33
Corticosubcortical spontaneous	58	26	32	0.81	65.97	69.62	7.62	95.50	18.35
Chronic subdural	30	15	15	1.00	76.81	78.36	37.39	91.70	11.80
Spontaneous subarachnoid	18	4	14	0.29	61.62	60.90	25.08	88.31	15.01

and Mediterranean diet, although sedentarism and obesity issues regarded as a growing epidemic; absence of documented peaks of vascular hereditary hemorrhagic pathologies; controlled crime situation and unpermissive use of guns by citizens; mandatory use of helmet by motorcyclists; restrictive speed limit, although concerns regarding its adequate supervision are common; reasonable road quality; and reasonable implementation of measures to prevent work accidents. This should be taken into account in the contextualization of the salient figures of this study that include an incidence rate of intracranial hemorrhage of 134.10/100,000/year; a global incidence rate of head injury of 767.48/100,000/year; incidence rates of hemorrhagic patterns more likely to be associated with a traumatic origin include acute subdural (49.69), contusion (21.55), and epidural (5.09), adding up to a global incidence rate of 76.33/100,000/year; and incidence rates of hemorrhagic patterns more likely to be associated with a spontaneous origin include basal ganglia (18.26), cerebral corticosubcortical spontaneous (17.36), spontaneous subarachnoid (5.39), cerebellar (2.99), and brainstem (1.20), adding up to a global incidence rate of 45.2/100,000/year, inferior to the one of trauma. When viewing the difference between these two figures, it is acknowledged that the categorization between traumatic and spontaneous origins may not be straightforward in selected situations. Head injury is the most frequent complaint motivating brain CT scan (30.11%), and in this context, hemorrhage is present in up to 7.76%. The presence of hemorrhage in 44.87% of post-operative CT scans does not imply a large volume; it includes operated hemorrhages and elective cases and is not synonym with post-operative hematoma requiring surgical evacuation. The “follow-up” category is

an unspecific clinical jargon that may harbor diverse situations; given that, this analysis employed the first CT scan of the sequence that patients performed, this category probably includes patients that suffered the original hemorrhagic event before the study period and that may justify the finding of 16.43% of hemorrhage; the number may also represent those patients that were diagnosed in private settings and then transferred to the public facility during the study period. Hemorrhage is present in 11.07% of cases of stupor, and this attests the severe clinical condition that hemorrhage may cause. Acute subdural, contusion, and epidural, classically of traumatic origin, add up to 56.91% of the patterns of hemorrhage found. Although more females undergo brain CT scan (M/F ratio 0.83), and even so in the context of head injury (M/F ratio 0.89), hemorrhage, in general, is more frequently encountered in males (M/F ratio 1.20), including the context of head injury (M/F ratio 1.58), but excluding spontaneous subarachnoid hemorrhage (M/F ratio 0.29) ($p < 0.05$ Fisher's exact with mid-P method). It can be hypothesized that males engage in more accident-prone behavior and adhere less to the control of neurovascular risk factors. Basal ganglia hemorrhage and chronic subdural hemorrhage seem to affect older people (mean age superior to 70) ($p < 0.05$ t-test). In the context of head injury and traumatic brain injury, focused published reviews emphasize the considerable variability that exists on the reported incidence rates due to very different inclusion criteria and effective regional variations, ranging from 7.3 to 811/100,000/year², with a mean of 262 in Europe³. Male predominance and mean age of occurrence ranging from 27 to 59.67 years have been reported as well². The concept of traumatic brain injury as “an alteration in brain function

or other evidence of brain pathology caused by an external force⁴ might encompass the cases here reported as head injury with intracranial hemorrhage (76.33/100,000/year obtained by summing acute subdurals, contusions, and epidurals); on the other hand, the complaint head injury alone would measure a much larger phenomenon that includes the very frequent minor trauma with no consequence (reported in the present study as 767.48/100,000/year). The population of the present study would rank low in the former situation (major trauma) and high in the latter (minor trauma). For intracerebral hemorrhage reported incidence rates per 100,000 person-years ranged from 19.6 to 51.85, and the population of the present study would rank high (39.81/100,000/year obtained by summing basal ganglia, cerebral corticosubcortical spontaneous, cerebellar, and brainstem). Spontaneous subarachnoid hemorrhage ranges from 4.2 to 22.7/100,000 person-years⁶; the population of the present study would rank low (5.39/100,000 person-years). Screening of vascular lesions with modern non-invasive imaging methods in selected high-risk groups is well established⁷, and if feasible, treatment before rupture is advocated in this setting, thereby minimizing the risk of hemorrhage. To what extent should these programs be implemented in settings of high incidence of intracranial hemorrhage could deserve further cost-effect analysis. Surveillance of intracranial hemorrhage incidence in large sampling geographical areas, such as performed in the present study, may disclose potential areas of intervention for the improvement of these rates and of the health status of the community.

Conclusion

In the population and in the period in study, traumatic patterns of hemorrhage seem to be slightly more frequent than those of spontaneous nature and head injury the most frequent indication for brain CT scan

study. Although within the ranges reported in literature, the incidence rates of hemorrhage that were found rank low for trauma and spontaneous subarachnoid and high for intracerebral. Reinforcement of measures aimed at the prevention of head trauma, control of neurovascular risk factors, and screening for vascular pathology may be in order. This indicator serves to characterize the health status of the community.

Acknowledgments

None.

Conflicts of interest

None.

Financing

None.

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Neuropsychological disorders in juvenile delinquents

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Abstract

Juvenile delinquents are young people who break the law. They are usually males of low socio-economic status and low education, and are more exposed to brain damage risk factors, especially drug use, and have a higher prevalence of attention deficit hyperactivity disorder. These characteristics suggest a delay in the development of the prefrontal cortex of the brain, which is related to neuropsychological functions such as language, memory, attention, and executive functions. To assess the evidence of a delay in the development of prefrontal functions, a search was conducted for studies that evaluated neuropsychological functions in inmate juvenile delinquents, comparing them to a control group, and only 14 articles were found with these characteristics. The review showed that, despite methodological issues on task selection and on the composition of control groups, there is evidence that juvenile delinquents have disorders on neuropsychological functions such as language comprehension, visuospatial working memory, selective and sustained attention, and components of executive functions such as cognitive inhibition, cognitive flexibility, and planning. These findings agree with the hypothesis that there is a developmental delay in the prefrontal functions of juvenile delinquents. Understanding the deficits juvenile delinquents have on neuropsychological functions is crucial to design prevention and treatment programs for juvenile delinquency.

Key words: Juvenile delinquency. Adolescence. Neuropsychology. Executive functions. Education.

Trastornos neuropsicológicos en delincuentes juveniles

Resumen

Los delincuentes juveniles son jóvenes que violan la ley. Por lo general, son hombres de bajo nivel socioeconómico que tienen poca educación, están más expuestos a factores de riesgo de daño cerebral, especialmente el uso de drogas y tienen una mayor prevalencia de TDAH. Estas características sugieren un retraso en el desarrollo de la corteza prefrontal del cerebro, que está relacionada con funciones neuropsicológicas como el lenguaje, la memoria, la atención y las funciones ejecutivas. Para evaluar la evidencia de un retraso en el desarrollo de las funciones prefrontales, se realizó una búsqueda de estudios que evaluaran las funciones neuropsicológicas en delincuentes juveniles internos, comparándolos con un grupo de control y solo se encontraron 14 artículos con estas características. La revisión mostró que, a pesar de los problemas metodológicos en la selección de tareas y en la composición de los grupos de control, existe evidencia de que los

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Date of reception: 22-03-2019

Date of acceptance: 23-04-2019

DOI: 10.24875/RMN.19000064

Available online: 30-10-2019

Rev Mex Neuroci. 2019;20(5):244-252

www.revexneurociencia.com

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delincuentes juveniles tienen trastornos en las funciones neuropsicológicas, como la comprensión del lenguaje, la memoria de trabajo visoespacial, la atención selectiva y sostenida y los componentes de las funciones ejecutivas como la inhibición cognitiva, la flexibilidad cognitiva y planificación. Estos hallazgos concuerdan con la hipótesis de que existe un retraso en el desarrollo de las funciones prefrontales de los delincuentes juveniles. Comprender los déficits que tienen los delincuentes juveniles en las funciones neuropsicológicas es crucial para diseñar programas de prevención y tratamiento para la delincuencia juvenil.

Palabras clave: Delincuencia juvenil. Adolescencia. Neuropsicología. Funciones ejecutivas. Educación.

Introduction

Juvenile delinquents are young persons that break the laws of a state or nation before being of legal age in that region, usually at 18 years of age¹. Only adults can be found guilty of an illegal act since younger persons lack the capacity to fully understand the negative consequences of their actions. Most juvenile delinquents commit only misdemeanors, such as fights, vandalism, and unarmed theft; nevertheless, some of these adolescents get involved in serious crimes such as homicide, sexual assault, organized delinquency, and kidnapping². Juvenile delinquency, compared to adult delinquency, causes a great part of the global number of lesions, premature deaths, and disabilities³. Juvenile delinquency also reduces productivity, the value of property, and the quality of life of the general population⁴.

Economic theories of delinquency propose that people respond to the costs and benefits of criminal activity⁵. Geographical theories focus on the distribution and environment where crimes happen and propose interventions on urban space⁶. Social theories explain delinquent behavior through the social and cultural conditions surrounding the juvenile delinquent and analyze variables such as peer influence, family relationships, race, ethnicity, poverty, neighborhood, and criminal subculture⁷.

Gender and socioeconomic status are two social factors that appear in every country where delinquency has been studied. The great majority of juvenile delinquents are males; for example, in Mexico the homicide rate is 10 times higher in males compared to females². Low socio-economic status is the norm in the juvenile delinquent population⁸, and it relates to other brain damage risk factors, such as less access to health and education services, greater exposure to illegal drugs, and a greater prevalence of family violence^{9,10}.

On the other hand, biological and psychological theories analyze the characteristics of the person that commits the crime, instead of its relations to the environment. Early biological explanations of delinquency

ended up supporting deterministic ideas, particularly Lombroso's concept of a "natural born criminal." Deterministic explanations take a single trait that is common among delinquents and portray it as the main cause or predictor of future delinquency. Trying to explain delinquency through a single cause is dangerous because it can bring social exclusion, mass incarceration, or even genocide to a social class, a race or an ethnic group living in disadvantageous conditions. Contemporary biological and psychological theories are mostly not deterministic, but it is common to notice attempts in politics and the media to isolate a risk factor and portray it as the major cause or explanation for delinquency¹¹.

A contemporary non-deterministic biological explanation stems from the premise that, if behavior depends on the brain, delinquent behavior must somehow be related to peculiarities of brain functioning or development. There is neurological and neuropsychological evidence enough to state the hypothesis that a delay in the development of the prefrontal cortex increases the risk of adolescents of getting involved in delinquency¹². Some of the evidence in juvenile and adult delinquents that supports this hypothesis is presented below.

Delinquents have a higher level of dopamine than controls; this neurotransmitter appears in the frontal cortex and is related to the display of aggression and cognition¹³. Adolescents with higher aggression have lower levels of orbitofrontal serotonin, a neurotransmitter related to pain detection and aggression inhibition¹⁴. This evidence suggests there are abnormalities in the prefrontal cortex neurotransmitters of adult delinquents.

The incidence of electroencephalographic abnormalities in adult delinquents is between 25 % and 50 %¹⁵, which suggests a reduction of the input that the reticular activating system has on the cortex and the rest of the brain; nevertheless, more studies are needed to confirm these findings.

Raine et al.^{16,17} showed, through positron emission tomography, that a group of adult delinquents had lower metabolic activity in the prefrontal cortex and other subcortical areas, compared to non-delinquents; a literature

review on functional neuroimaging in delinquents confirms these findings¹⁸. Adolescents living in reformatories with high indices of violence and aggression showed greater activity in the fusiform gyrus, recorded through functional magnetic resonance when presented with violent images¹⁷. Nevertheless, another study using magnetic resonance did not find differences in prefrontal activation during an economic task, which suggests juvenile delinquents activate similar neural networks than controls during decision making, despite having worse results¹⁹. Alterations in the gray and white matter morphology of the brain have been reported in delinquents with aggressive or violent behavior²⁰.

Most of these studies were done after the crimes were committed; therefore, it is difficult to determine that these findings were not due to the incarceration process. Nevertheless, these results suggest that juvenile delinquents have differences in the structure and functioning of the brain that could result in a delay of prefrontal development.

Some factors associated with a delay in prefrontal development that are common in the juvenile delinquent population are early malnourishment²¹, drug use²², and traumatic brain injuries²³. Lewis et al.²³ reported that juvenile delinquents are in a higher risk of having suffered parental negligence, which affects brain development and lowers cognitive capacity. Furthermore, juvenile delinquents have more emergency room visits for severe head or face trauma than other adolescents, which can alter brain development²⁴.

Juvenile delinquents also have problems to learn at a similar pace as other adolescents, especially while learning to read, write, and calculate²⁵ and have a greater prevalence of academic failure¹¹; these school problems are usually interpreted as a delay in the development of cerebral circuits. Juvenile delinquents that have learning problems have been found to have a higher index of recidivism, compared to other delinquents with better academic performance²⁶. Even though not all adolescents with school problems commit felonies²⁷, school abandonment has been related to a greater probability of getting involved in criminal activities²⁸.

In terms of psychiatric disorders, conduct disorder (CD) and oppositional defiant disorder are expected in juvenile delinquents, since some of the criteria for their diagnosis includes arrests and trouble with the police. On the other hand, depression and anxiety have a high prevalence in juvenile delinquents²⁹, these disorders have been related to an alteration of prefrontal activity and its influence in the limbic system³⁰, suggesting a prefrontal alteration.

Juvenile delinquents usually have problems with drug use, for example, 8% of school attending adolescents in the United States report abuse or dependence on alcohol or drugs, but this prevalence increases to 23% in arrested adolescents³¹. Most juvenile delinquents report having started using drugs the year before their first felony, but others report having committed crimes to sustain their habit³². Drug use can alter neurotransmitter metabolism and the number of synaptic receptors in the brain³³ and it has been related to low performance in neuropsychological tests that evaluate reticular, parietal, and frontal lobe functions³⁴, specifically on memory,³⁵ and executive functions tasks³⁶.

Besides having a negative impact on brain development, drug use has been related to a diagnosis of attention deficit hyperactivity disorder (ADHD)³⁷ because these patients have greater indices of use and abuse of substances than other adolescents³⁸. This relationship is not yet clear since it has not been possible to determine if drugs are part of the causes of ADHD or if ADHD patients use drugs as a form of self-medication³⁹.

Adolescents with more childhood ADHD symptoms tend to commit more misdemeanors at a younger age than those without the disorder⁴⁰. ADHD has been related to a delay in the development of prefrontal areas; therefore, the high prevalence of this disorder among juvenile delinquents⁴¹ suggests that these youngsters have a delay in prefrontal development. This delay would manifest as immaturity in neuropsychological functions such as attention, memory, and executive functions⁴².

These characteristics suggest that juvenile delinquents are an at-risk group for having a delay in the development of the prefrontal cortex. It is possible that this delay manifests as neuropsychological disorders, increasing the chances for school dropout, which combined with poverty, family issues, and other mental health problems leave adolescents with few options, and vulnerable to get involved in criminal groups. Nevertheless, although there are many analyses of these functions in juvenile delinquents, they need to be sorted and discussed to evaluate the neuropsychological evidence of a developmental delay of the prefrontal cortex. Therefore, the objective of this revision is to analyze the evidence of neuropsychological disorders in juvenile delinquents.

Methods

The present study is an integrative review that collects, analyzes, and synthesizes evidence from diverse

sources while clearly stating the search criteria. A search for journal articles was performed using combinations of the terms “juvenile delinquency,” “delinquent adolescent,” “juvenile offenders” or “young delinquents” with “neuropsychology,” “attention” and “executive functions” on three search engines: *Google Scholar*, *Medline*, and *Redalyc*.

For an article to be included in the revision it had to be published between January 1980 and April 2018, in English or Spanish, have an experimental group formed by adolescents residing at a center for committing a crime, have a control group of non-delinquent adolescents, and the use of a neuropsychological task. All articles were from peer-reviewed journals, except two theses that covered the other requirements and were included due to their relevance. A longitudinal analysis authored by Moffit and her team was also included because of its great influence in the field; nevertheless, it was not included in the results table. Articles were excluded for: not having a sound neuropsychological assessment and for forming an experimental group through self-reports of delinquent behavior, or with adolescents that were not legally responsible for a crime. With these criteria, 25 articles were taken into account, and in a closer analysis ten were discarded, to finally include 14 articles in this review (Table 1).

Analysis and discussion

The articles were grouped by the neuropsychological functions that are evaluated. The method and results of each article are discussed in the text; the particular tasks and indices that were used and the scores that each group obtained are detailed in table 1.

Language

Juvenile delinquents have difficulties on complex aspects of language, such as verbal fluency⁴³, production of complex sentences, and verbal comprehension, in comparison to adolescents without legal problems and of similar age, race, and socio-economic status to the juvenile delinquent group⁴³⁻⁴⁶. These differences were determined using subtests of the Wechsler intelligence scales and the Clinical Evaluation of Language Fundamentals. Comprehension and verbal fluency are related to the functioning of the prefrontal cortex; these results suggest a delay in the development of these areas, and therefore on other prefrontal functions.

Memory

Even though memory is a basic cognitive process, it has been analyzed scarcely. A study reported juvenile delinquents had lower scores on a verbal learning task, which heavily recruits memory, meaning they had a lower capacity to improve their recall of a word list during subsequent exposures, compared to other student adolescents⁴⁷. A longitudinal study showed a weak correlation (under 0.20) between number of arrests and the score of this same task during adolescence years⁴⁸.

Working memory is the capacity to recall relevant information for the task at hand and has three components: the visuospatial storage, the phonological storage, and the central executive component. In the spatial working memory task, juvenile delinquents had a low level of performance compared to control adolescents^{49,50}. Other studies that measured visuospatial working memory through the Benton visual retention test report more errors in juveniles, compared to controls paired by socioeconomic status (SES), sex, and ethnicity^{43,51}.

These results indicate that juvenile delinquents have a deficit on the visuospatial component of working memory, which is the capacity to store the position of objects in space; nevertheless, more studies are needed to analyze the remaining components. These results could also be due to an alteration in the central executive component of working memory, in charge of prioritizing the storage of task-relevant information in the visuospatial or phonological storages and, when affected, it greatly disturbs the functioning of the other two components. This component is more directly related to prefrontal functioning, and therefore a delay in prefrontal development could reduce performance on working memory tasks, such as it is observed in juvenile delinquents.

Attention

The majority of the reviewed studies focus on evaluating a single component of attention and employ tasks with indices that are not sensible enough. Olvera et al.⁴⁴ did not find differences in selective attention when comparing a juvenile delinquent group to a group of adolescents of the same community, age, sex, ethnicity, and similar SES. This study employed a cancellation task with a very low demand that was probably not sensitive to group differences. On the other hand, Chae et al.⁵² reported that juvenile

Table 1. Neuropsychological studies of juvenile delinquents

First author	Experimental and control groups	Paired by	Function	Tasks and tests	Indices	Group score comparison (E: Experimental, C: Control)
Abdou (2011)	25 juvenile delinquents 15 adolescent students	Age, sex, SES	Cognitive flexibility	WCST	Perseverative responses	Males: E: 33 C: 9.2 Female: E: 22.6 C: 9.6
Appellof (1985)	23 juvenile delinquents 29 adolescent students	Age, ethnicity, sex, SES	Cognitive flexibility Executive functions Planning	WCST	Perseverative responses	E: 20.39, C: 16.72
				Porteus maze	Number of categories	E: 4.96, C: 4.76
			Verbal fluency	TVF	Qualitative score	E: 27.35, C: 22.07
			Verbal comprehension Visuospatial memory	Token Test	Correct responses	E: 14.87, C: 17.45
				BVRT	Correct responses	E: 36.65, C: 37.62
Blanton (2007)	18 juvenile delinquents 14 adolescent students	Age, race, SES	Language Executive functions Language	KBIT subtests	Vocabulary score	E: 86.3, C: 93.2
				CELF-3	Matrices score Receptive score Expressive score	E: 99.0, C: 101.9 E: 88.6, C: 99.1 E: 90.7, C: 99.6
Borrani (2011)	12 juvenile delinquents 26 normal education adolescents 12 low-education adolescents	Age, sex, education	Sustained attention	Continuous performance task	Percentage of correct responses	JD: 77.11 NE: 94.96 LE: 80.22
					DS of correct responses	JD: 2.37 NE: 0.90 LE: 2.46
					R of correct responses	JD: -0.10 NE: -0.20 LE: 0.09
Borrani (2015)	27 juvenile delinquents 27 low-education adolescents 27 normal education adolescents	Age, sex, education	Cognitive inhibition	Modified Stroop task	Word reading	JD: 23.93 LE: 24.48 NE: 23.56
					Color naming	JD: 53.22 LE: 57.56 NE: 45.74
			Cognitive flexibility		Switching errors	JD: 68.39 LE: 74.54 NE: 62.19
Carrol (2006)	43 juvenile delinquents 43 adolescent students	Age, sex	Cognitive inhibition	Stroop task	Word reading Color naming Interference	E: 34.38, C: 43.17 E: 34.93, C: 42.21 E: 51.38, C: 55.29
Caufman (2005)	78 Juvenile delinquents 78 Adolescent students	Age, ethnicity, SES	Planning	Tower of London Spatial Working Memory	Problems completed	E: 8.51, C: 8.46
			Spatial working memory		Strategy score (overall performance)	E: 36.20, C: 34.56
Chae (2001)	17 juvenile delinquents 47 adolescent students	Age, sex, SES	Attention	Test of variables of attention	Omissions Commission RT variability Decrement in performance	E: 1.56 , C: 1.37 E: 4.14, C: 2.55 E: 89.60, C: 89.27 E: 4.29, C: 5.12

(Continues)

Table 1. Neuropsychological studies of juvenile delinquents (*Continued*)

First author	Experimental and control groups	Paired by	Function	Tasks and tests	Indices	Group score comparison (E: Experimental, C: Control)
Lueger (1990)	21 juvenile delinquents (with a diagnosis of CD) 20 adolescents from a community center	Age, sex Planning	Cognitive flexibility Executive attention Sustained attention Verbal memory Planning	WCST SMMT AVLT Trail making test	Perseverative responses Number of categories Number of errors Learning Time (seconds)	E: 44.50, C: 20.62 E: 3.14, C: 4.58 E: 17.77, C: 9.45 E: 2.69, C: 3.38 E: 39.27, C: 30.71
Olvera* (2005)	16 juvenile delinquents 26 adolescents from the community	Age, sex, ethnicity, SES	Cognitive inhibition Cognitive flexibility Planning	Stroop WCST Tower of London	Word reading Perseverative responses Number of moves	E: 97.2, C: 107.8 E: 90.2, C: 111.9 E: 104.6, C: 90.2
Poon* (2014)	29 juvenile delinquents with ADHD 29 adolescent students	Age, sex, SES	Cognitive inhibition Visuospatial memory Planning	Stroop BVRT Tower of London	Interference Total errors Number of moves	E: 0.16, C: 0.30 E: 0.70, C: 0.06 E: 0.14, C: 0.01
Romi (2007)	111 juvenile delinquents 31 adolescent students	Age, sex, education	Language	WISC	Vocabulary score	E: 8.52 C: 10.27
Wolf (1984)	56 juvenile delinquents 48 adolescent students	Age, sex, SES	Language Cognitive inhibition Selective attention Planning	TBNT Token test Stroop Trail making test Porteus maze	Correct responses Correct responses Word reading (time) Color naming (time) Interference index Perceptual errors Qualitative score Correct responses	E: 28.4 C: 32.7 E: 15.8, C: 17.3 E: 55.0, C: 46.4 E: 75.5, C: 67.1 E: 140.7, C: 129.1 E: 9.9, C: 5.6 E: 18.8, C: 9.0 E: 72.1, C: 72.7

WCST: Wisconsin Card Sorting Test; CELF-3: clinical evaluations of language fundamentals; SMMT: sequential matching memory test; AVLT: auditory verbal learning test; BVRT: Benton visual retention test; TBNT: the Boston naming test; SD: standard deviation; SES: socioeconomic status; KBIT: Kaufman brief intelligence test.

*These studies report only their transformed data and the method of transformation is not entirely clear.

delinquents had a higher percentage of commission errors, compared to a group of adolescents of normal education and similar SES, which could be taken as index of selective attention; although significant, these differences between groups were small. On this same study, the decrement of performance was analyzed and found to be steeper in juvenile delinquents compared to controls, indicating a deficit on sustained attention in juvenile delinquents.

Another study⁵³ analyzed this process with a neuropsychological task that evaluates sustained attention, which is the capacity to respond at the same level during a prolonged period. Sustained attention is related to prefrontal cortex functioning⁵⁴. This study found that juvenile delinquents had difficulties on this component of attention, compared with normal-education adolescents; it also found a deficit on sustained attention on an education-paired group, compared to a more

educated group. These results indicate that juvenile delinquents have a developmental delay in prefrontal functions and its connections to the reticular system.

Regarding attention, this study was the only one found to consider the education of the participants, and the only one that tried to control this factor by incorporating a control group with the same age and education as the juvenile delinquent group. Through this protocol, differences in attention surfaced between groups of different education, since low-education adolescents (delinquents and non-delinquents) had the same low attention capacity, which suggests that these deficits are related to low education, and therefore not directly related to legal status. Even though attention problems and school dropout appear in juvenile delinquents, they are not a direct cause of delinquency.

Executive functions

The components of executive functions are initiative, planning, prevision, cognitive inhibition, cognitive flexibility, self-monitoring, verification, and correction⁵⁵. These functions are denominated as “executive” due to their role in regulating other brain functions that have a much more limited and specific operative roles⁵⁶.

Executive functions are related to the prefrontal cortex, and lesions in the dorsolateral area of this cortex usually produce disorders in cognitive inhibition, the capacity to stop prevalent responses. This manifests as impulsive behavior⁵⁷, responding to irrelevant stimuli, producing answers out of time, out of context, or that interfere with actions directed to a goal, for example, making inappropriate and offensive commentaries⁵⁸.

On the other hand, a great part of prefrontal lesion patients shows deficits in cognitive flexibility, the capacity to change behavior based on environmental cues, which impairs the formulation of a different strategy to solve a new problem⁵⁹. This perseverative behavior makes patients persist on the same response strategy, even though they can acknowledge it is not working⁵⁷.

Patients with prefrontal lesions also have deficits on planning, meaning they have difficulties setting goals, selecting the action strategies pertinent to achieve them, and executing the behavior sequence that is required to reach those goals⁵⁶. This deficit affects daily life, making prefrontal patients break more rules, omit necessary behaviors, and perform actions unrelated to the proposed goal, especially when confronting new and unstructured problems^{56,59}. Prefrontal patients

commit more mistakes and require more time to solve tasks that evaluate planning, such as the Tower of London and the Porteus Maze⁶⁰.

Juvenile delinquents have low scores on the performance of neuropsychological tasks related to executive functions^{43,61}. Olvera et al.⁴⁴ found that a group of inmate juvenile delinquents had worse performance on a Stroop-type task, compared to middle-class adolescents of the same age, sex, and race, which indicates juvenile delinquents have lower cognitive inhibition. Other studies that employed other Stroop-like tasks also reported significative differences in the indices of inhibition^{51,62}.

Another study found that juvenile delinquents have deficits on inhibition using a modified Stroop task⁶⁴, compared to adolescents of normal education; nevertheless, these difficulties were also observed in a group of low education non-delinquents. Therefore, juvenile delinquents have a deficit on cognitive inhibition, and this deficit is shared between delinquents and non-delinquents of low-education; this implies that this deficit is probably related to their school problems, which is a risk factor for involvement in criminal activities. This study is the only one on executive functions that takes education into account and attempts to control its effect through a group paired by education.

On cognitive flexibility, Lueger and Gill⁴⁷ found that a group of juvenile delinquents (diagnosed with CD) had more perseverative responses on the Wisconsin Card Sorting Test (WCST), compared to a group of adolescents paired by verbal IQ and race, but that had no symptoms of CD and no criminal history. Nevertheless, this result could be influenced by the fact that the control group had a mean age 1 year older than the inmate group. Appellof⁴³ reported that juvenile delinquents had more perseverative responses on the WCST than a group of adolescents of the same age, race, sex, and socioeconomic status. Olvera et al.⁴⁴ compared two groups, similar to the Appellof pairing, reporting a greater quantity of perseverative responses on behalf of juvenile delinquents. Abdou et al.⁶⁵ found in a study with male and female juvenile delinquents that both groups had a greater number of perseverative responses on the WCST, compared to the control groups. Nevertheless, even though the groups were paired by age, the control group had more education years than the delinquent group. Finally, Zou et al.⁵⁰ did not find differences between the perseverative responses of the delinquent group and the control group, and the groups had a difference in education of three school years.

On the other hand, juvenile delinquents with a diagnosis of bipolar disorder or CD needed ten more movements to solve the Tower of London, a task related to planning and prevision⁴⁴, compared to a control group paired by age, sex, ethnicity, and SES. Using this same task, Appellof⁴³ found a lower quantity of correctly solved problems in juvenile delinquents in comparison with a control group. Zou et al.⁵⁰ reported differences between juvenile delinquents and controls in a similar task but on another index, the total number of problems solved. Cauffman et al.,⁴⁹ on the other hand, did not find differences in the quantity of solved problems in the Tower of London compared to a control group, similarly to Poon and Ho⁵¹, both using the same index. Lueger and Gill⁴⁷ took the time to finish the trail making test as index for planning and found longer times in the delinquent group compared to adolescent students.

Since executive functions have a modulating role on the rest of neuropsychological functions, it is possible that the low-performance that juvenile delinquents show on intelligence, language, memory, and attention tasks are explained by their difficulties in executive functions. Nevertheless, the relationship between executive functions disorders and delinquent behavior is not necessarily causal⁶⁶.

Even though there is evidence that juvenile delinquents have a deficit on cognitive inhibition, cognitive flexibility, and planning, there are contradictory results, which could be due to differences in the conceptualization of executive functions, to poor selection of tasks indices to assess its components and finally, to the lack of adequate control groups⁶⁷. A common methodological problem in these studies is the lack of control of the participant's education. This is particularly serious since juvenile delinquents have a lower education level and the great majority of neuropsychological tasks are affected by education, making it unclear if these executive functions deficits are related to the legal status of adolescents or their lower education⁶⁷. Some authors state that the crimes of juvenile delinquents may be due to their difficulties in executive functions, which make them react inadequately to the environment⁶⁸. Nevertheless, at least one of the reviewed studies demonstrated that juvenile delinquents have the same problems in executive functions than other adolescents of the same age and education but that had committed no crimes, thus proving that the delinquent behavior of these adolescents cannot be fully explained by their deficits on executive functions. Similarly, not all patients with disorders on executive functions have aggressive or violent behavior⁶⁷.

It is important to notice that a disorder on executive functions affects almost invariably on academic performance⁶⁸ and that low academic performance is the main reason for school dropout. Silberberg and Silberberg⁶⁹ state that low education and school dropout are the factors that most increase the risk for an adolescent to get involved in criminal activities. Nevertheless, it is evident that not all adolescents with school problems or all patients with prefrontal deficits or ADHD become juvenile delinquents, therefore making it dangerous to state a causal relationship between these factors and criminal behavior. Nevertheless, early interventions in these neuropsychological deficits can improve protective factors and deter adolescents from criminal activities.

Conclusions

The literature reviewed shows that juvenile delinquents have neuropsychological disorders on language, working memory, selective, and sustained attention, besides disorders on components of executive functions such as planning, cognitive inhibition, and flexibility. These findings support the hypothesis that juvenile delinquents have a delay in the development of the prefrontal cortex. It is important to analyze how the combination of these neuropsychological disorders and other social factors raise the risk of getting involved in criminal activities, to prevent school dropout and juvenile delinquency.

Conflicts of interest

The authors here declare that there are no conflicts of interest in this article review.

Source of financing

This study had no funding of any kind.

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