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### التعريف بالمجلة

تصدر مجلة الدراسات والبحوث التربوية عن مركز العطاء للاستشارات التربوية- دولة الكويت بالتعاون مع كلية العلوم التربوية- جامعة الطفيلة التقنية- الأردن كل أربعة شهور، وهي مجلة علمية دورية محكمة بإشراف هيئة تحرير وهيئة علمية تضم نخبة من الأساتذة، وتسعى المجلة للإسهام في تطوير المعرفة ونشرها من خلال طرح القضايا المعاصرة في مختلف التخصصات التربوية، والاهتمام بقضايا التجديد والإبداع، ومتابعة ما يستجد في مختلف مجالات التربية؛ والمجلة مفهرسة في العديد من قواعد المعلومات الدولية، ومنها: دار المنظومة Dar Almandumah، معرفة e- MAREFA، شمعة Shamaa، قاعدة المعلومات التربوية Edu Searach، وللمجلة معامل تأثير عربي.

### أهداف المجلة

- تهدف المجلة إلى دعم الباحثين في مختلف التخصصات التربوية من خلال توفير وعاء جديد للنشر يلبي حاجات الباحثين داخل الكويت وخارجها. ويمكن تحديد أهداف المجلة بشكل تفصيلي في الأهداف الأربعة التالية:
1. المشاركة الفاعلة مع مراكز البحث العلمي لإثراء حركة البحث في المجال التربوي.
  2. استنهاض الباحثين المتميزين للإسهام في طرح المعالجات العلمية المتعمقة والمبتكرة للمستجدات والقضايا التربوية.
  3. توفير وعاء لنشر الأبحاث العلمية الأصيلة في مختلف التخصصات التربوية.
  4. متابعة المؤتمرات والندوات العلمية في مجال العلوم التربوية.

## مجالات النشر في المجلة

تهتم مجلة الدراسات والبحوث التربوية بنشر الدراسات والبحوث التي لم يسبق نشرها في مختلف التخصصات التربوية، على أن تتصف بالأصالة والجدة، وتتبع المنهجية العلمية، وتراعي أخلاقيات البحث العلمي. كما تنشر المجلة ملخصات رسائل الماجستير والدكتوراه ذات العلاقة بمختلف التخصصات التربوية، والمراجعات العلمية، وتقارير البحوث والمراسلات العلمية القصيرة، وتقارير المؤتمرات والمنتديات العلمية، والكتب والمؤلفات المتخصصة في التربية ونقدها وتحليلها.

## القواعد العامة لقبول النشر في المجلة

1. تقبل المجلة نشر البحوث باللغتين العربية والإنجليزية وفقاً للمعايير التالية:

- توافر شروط البحث العلمي المعتمد على الأصول العلمية والمنهجية المتعارف عليها في كتابة البحوث الأكاديمية في مجالات التربية المختلفة.
  - أن تحتوي الصفحة الأولى من البحث على:
    - اسم الباحث ودرجته العلمية والجامعة التي ينتمي إليها.
    - البريد الإلكتروني للباحث، ورقم الهاتف النقال.
    - ملخص للبحث باللغة العربية والإنجليزية في حدود (150) كلمة.
    - الكلمات المفتاحية بعد الملخص.
  - ألا يزيد عدد صفحات البحث عن (30) صفحة متضمنة الهوامش والمراجع.
  - أن تكون الجداول والأشكال مُدرجة في أماكنها الصحيحة، وأن تشمل العناوين والبيانات الإيضاحية الضرورية، ويُراعى ألا تتجاوز أبعاد الأشكال والجداول حجم الصفحة.
  - أن يكون البحث ملتزماً بدقة التوثيق حسب دليل جمعية علم النفس الأمريكية APA الإصدار السادس، وحسن استخدام المصادر والمراجع، وتثبيت مراجع البحث في نهايته.
  - أن يكون البحث خالياً من الأخطاء اللغوية والنحوية والإملائية.
  - أن يلتزم الباحث بالخطوط وأحجامها على النحو التالي:
    - اللغة العربية: نوع الخط (Sakkal Majalla)، وحجم الخط (14).
    - اللغة الإنجليزية: نوع الخط (Times New Roman)، وحجم الخط (14).
    - تكتب العناوين الرئيسية والفرعية بحجم (16) غامق (Bold).
    - أن تكون المسافة بين الأسطر (1.15) بالنسبة للبحوث باللغة العربية، وتكون المسافة بين الأسطر (1.5) بالنسبة للبحوث باللغة الإنجليزية.
    - تترك مسافة (2.5) لكل من الهامش العلوي والسفلي والجانبين.
2. ألا يكون البحث قد سبق نشره أو قُدم للنشر في أي جهة أخرى.
3. تحتفظ المجلة بحقها في إخراج البحث وإبراز عناوينه بما يتناسب وأسلوبها في النشر.

4. ترحب المجلة بنشر ما يصلها من ملخصات الرسائل الجامعية التي تمت مناقشتها وإجازتها في مجال التربية، على أن يكون الملخص من إعداد صاحب الرسالة نفسه.

5. بالمجلة باب لنشر موضوعات تهتم المجتمع التربوي يكتب فيه أعضاء التحرير.

### إجراءات النشر في المجلة

1. ترسل الدراسات والبحوث وجميع المراسلات باسم رئيس تحرير مجلة الدراسات والبحوث التربوية على الإيميل التالي: [submit.jser@gmail.com](mailto:submit.jser@gmail.com)

2. يرسل البحث إلكترونياً بخطوط متوافقة مع أجهزة (IBM)، بحيث يظهر في البحث اسم الباحث ولقبه العلمي، ومكان عمله.

3. يُرفق ملخص البحث المراد نشره في حدود (100-150 كلمة) سواء كان البحث باللغة العربية أو الإنجليزية، مع كتابة الكلمات المفتاحية الخاصة بالبحث (Key Words).

4. يرفق مع البحث موجز للسيرة الذاتية للباحث.

5. في حالة قبول البحث مبدئياً يتم عرضه على مُحكمين من ذوي الاختصاص في مجال البحث، لإبداء آرائهم حول مدى أصالة البحث وقيمه العلمية، ومدى التزام الباحث بالمنهجية المتعارف عليها، وتحديد مدى صلاحية البحث للنشر في المجلة من عدمها.

6. يُخطر الباحث بقرار صلاحية بحثه من عدمها خلال شهر من تاريخ استلام البحث.

7. في حالة ورود ملاحظات من المحكمين تُرسل إلى الباحث لإجراء التعديلات اللازمة، على أن يعاد إرسال البحث بعد التعديل إلى المجلة خلال مدة أقصاها شهر، ولا يجوز سحب البحث من المجلة بعد تحكيمه.

8. تؤول جميع حقوق النشر للمجلة.

9. لا تلتزم المجلة بنشر كل ما يرسل إليها.

10. المجلة لا ترد الأبحاث المرسلة إليها سواء كانت منشورة أو غير قابلة للنشر، وللمجلة وإدارتها حق التصرف في ذلك.

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## الافتتاحية

بسم الله الرحمن الرحيم، عليه نتوكل وبه نستعين، نحمده سبحانه كما ينبغي أن يحمد ونصلي ونسلم على أشرف المرسلين سيدنا محمد وعلى آله وأصحابه والتابعين وبعد،،

يشهد العالم ثورة معلوماتية كبرى منذ منتصف القرن الماضي بسبب التطور السريع والهائل لتكنولوجيا الإعلام والاتصال، وقاد هذا إلى تغير العديد من المفاهيم والأسس داخل المجتمع، فلم تعد المعدات والآلات الثقيلة ورأس المال الأدوات الرئيسية للنشاط الاقتصادي، إذ حلت محلها المعرفة التي أصبحت المحرك الأساسي للنشاط الاقتصادي والفرد في كل المجتمعات، وقد أدى تزايد قيمة المعرفة في العصر الحالي إلى أن أصبحت هي الطريق نحو مجتمع المعرفة الذي تتنافس الدول في تحقيقه.

وقد جعل ذلك الدول المتقدمة تنفق حوالي (20%) من دخلها القومي في استيعاب المعرفة، ويستحوذ التعليم على نصف هذه النسبة، كذلك تنفق المنظمات الصناعية والتجارية في هذه الدول ما لا يقل عن (5%) من دخلها الإجمالي في التنمية المهنية للعاملين بها، وتنفق ما يتراوح بين (3%-5%) من دخلها الإجمالي في البحث والتنمية.

ويعد البحث العلمي الوسيلة الرئيسية لإيجاد المعرفة وتطويرها وتطبيقها في المجتمع، كما يشكل الركيزة الأساسية للتطور العلمي والتقني والاقتصادي، ويساهم في رقي الأمم وتقدمها، وهو بمثابة خطوة للابتكار والإبداع، ويمثل البحث العلمي إحدى الركائز الأساسية لأي تعليم جامعي متميز، ويعد من أهم المعايير التي تعتمدها الجهات العلمية في تصنيف وترتيب الجامعات سواء على المستوى المحلي أو القومي أو العالمي؛ ويقاس التقدم العلمي لبلد من البلدان بمدى الناتج البحثي والعلمي مقارنةً بالدول الأخرى.

ويسر مجلة الدراسات والبحوث التربوية أن تقدم لقراءها هذا العدد، وتتقدم أسرة المجلة بالشكر إلى جميع الباحثين الذين ساهموا بأبحاثهم في هذا العدد، وتجدد دعوتها لجميع الباحثين للالتفاف حول هذا المنبر الأكاديمي بمساهماتهم العلمية. وندعو الله عز وجل السداد والتوفيق.

رئيس التحرير

أ.د/ علي حبيب الكندري

تخلي أسرة تحرير المجلة مسؤوليتها عن أي انتهاك لحقوق الملكية الفكرية، والآراء والأفكار الواردة في الأبحاث المنشورة لا تلزم إلا أصحابها جميع الحقوق محفوظة لمجلة الدراسات والبحوث التربوية © 2020



## Associations between obesity and cognitive function among Kuwaiti female university students

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**Abstract:** Obesity has adverse cognitive effects, but which specific cognitive functions are impaired by obesity remains unclear. The present study aimed to test for associations between obesity defined by BMI and high body fatness and performance in the Stroop Colour Word Test (SCWT) in Kuwaiti adolescent and young adult females. Data was collected from 400 female Kuwaiti students. SCWT performance was significantly lower in the students with obesity vs those without obesity as defined by BMI. SCWT performance was also significantly lower in the students with high body fatness vs those with lower body fatness. Those defined as having obesity by BMI were more likely to be in the lowest quartile for SCWT performance. Students with higher fatness were also at significantly higher risk of being in the lowest quartile for SCWT. SCWT performance was not affected by confounding variables considered. In conclusion, Obesity may impair SCWT performance in young females.

**Keywords:** Body composition; Body Mass Index; Cognition; Executive function; Obesity

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## Introduction:

Worldwide obesity has dramatically increased in the last few decades. Obesity is a major concern for public health due to high prevalence combined with increased risk of many medical problems.

In Kuwaiti children and adolescents, obesity rates are growing (Boodai & Reilly, 2013; Elkum *et al.*, 2016) and a recent systematic review highlighted that the prevalence of obesity in school-age children and adolescents has reached alarming levels in Kuwait (Al Hammadi & Reilly, 2019). Systematic reviews and other reports have also indicated that obesity may have a negative impact on educational attainment (Santana *et al.*, 2017; Martin *et al.*, 2017) and on cognitive processes relevant to educational attainment (Martin *et al.*, 2016; Okorodudu *et al.*, 2010; Yang *et al.*, 2018; Catoira *et al.*, 2016; Reinert *et al.*, 2013).

Booth *et al.*, (2014) tested the longitudinal association between obesity and academic attainment in a large UK cohort of adolescents. They found that girls with obesity at 11 years old had lower academic attainment compared with peers without obesity. Importantly, this association was not detected in boys and this may suggest gender differences or different mechanisms underlying the relationship between adolescent obesity and academic attainment. In addition, this association was found independent after controlling for some potential mediators, which may suggest a causal relationship between obesity and low academic attainment in female adolescents.

A systematic review of 34 studies between 1990 and 2016 reported a negative association between obesity and academic performance in school children and adolescents (Santana *et al.*, 2017). Another systematic review of 31

studies suggested that the association between childhood obesity and academic performance may differ by age, sex, and school subject. They found a significant negative association between obesity and mathematics attainment in adolescent girls, but not in boys. However, there was no clear association between obesity and reading or science achievement in boys and girls (Martin *et al.*, 2017).

With regards to the impact of obesity on college and university students performance, a systematic review of 16 studies showed that students with obesity had lower academic achievement compared to their normal weight peers, and female students were more likely to be affected than males (Hill *et al.*, 2019).

The negative association between obesity and academic performance can be partly explained by the neurocognitive effects of obesity. Several studies have reported a correlation between cognitive function and educational attainment (Spinath *et al.*, 2006; Bathelt *et al.*, 2019). In addition, other studies have established an association between the comorbidities of obesity and lower cognition and educational attainment in adolescents (Yau *et al.*, 2012; Lande *et al.*, 2012).

Executive functions are more likely to be impaired by obesity than other cognitive functions (Reinert *et al.*, 2013; Anderson *et al.*, 2019). Executive functions have been defined as the “higher cognitive processes that allow forethought and goal-directed action” (Reinert *et al.*, 2013). There are other definitions of executive function, for example, it has also been defined as “the capacity to think before acting, retain and manipulate information, reflect on the possible consequences of specific actions, and self-regulate behaviour” (Catoira *et al.*, 2016).

This set of mental skills includes cognitive inhibition, cognitive flexibility and working memory (Okorodudu *et al.*, 2010; Yang *et al.*, 2018). A systematic review reported that individuals with obesity may perform differently to healthy controls in performance tasks, which measure inhibitory control (Kulendran *et al.*, 2017). Disinhibited eating in adolescents with obesity was associated with orbitofrontal volume reductions and executive dysfunction (Maayan *et al.*, 2011). High BMI may have a significant effect on cognitive flexibility in young adults, with associated frontal lobe dysfunction and deficits in cognitive control (Steenbergen & Colzato, 2017). Additionally, the risk of lower cognitive performance related to obesity may be gender related and females may be at greater risk compared to males (Sabia *et al.*, 2009). Understanding the specific processes which might be impaired by obesity may help in providing more information about the cognitive mechanisms of effect, and might also be useful as a driver of future strategies aimed at obesity prevention.

Aspects of executive function have been measured by using many different tools, but one common tool is the Stroop Test, which can be used to measure selective attention, response inhibition, cognitive flexibility, and short-term memory (Din *et al.*, 2019; Wright, 2017). In this current study, we have used the Stroop Colour Word Test (SCWT) to evaluate selective attention and cognitive inhibition, as there was some previous evidence that obesity might impair these processes (Booth *et al.*, 2014). In addition, variables such as inhibition might be important to the maintenance of obesity via disinhibited eating (Preuss *et al.*, 2019) and performance on the Stroop Test may be relevant to academic attainment (Santana *et al.*, 2017). In our previous study, we showed that overall academic performance in female Kuwaiti students was lower in those with obesity than those without obesity (Al Hammadi *et al.*, 2020).

There is some skepticism about the possible effects of obesity on cognitive processes because most human studies have taken place in high-income western countries (Santana *et al.*, 2017; Martin *et al.*, 2016). In such countries relationships between obesity and cognitive outcomes may be confounded by socioeconomic status (low socio-economic status associated with both obesity and impaired cognition and educational attainment) (Santana *et al.*, 2017; Martin *et al.*, 2016); and so there is a need to test for associations where confounding of this kind is reduced, such as Kuwait (Al Hammadi & Reilly, 2019).

**The study seeks to answer the following question:**

Are there any associations between obesity defined by both BMI and high body fatness and Stroop test performance in a sample of late adolescent and young adult females in Kuwait?

**Objective of the study:**

Identifying the associations between obesity defined by both BMI and high body fatness and Stroop test performance in a sample of late adolescent and young adult females in Kuwait.

**The importance of the study:**

- Providing evidence on the association between obesity and cognitive function from Kuwait would be especially important because the population of Kuwait is relatively homogenous with less variation in socioeconomic status than in Western countries, giving more reliable data that is free of confounding.
- The findings of this study may contribute to developing policies addressing the problem of obesity and its consequences in Kuwait and the Gulf region.



### The limits of the study:

- Objective Limitations: The study was limited to testing the association between obesity and cognitive inhibition among female students of the Social Science College in the State of Kuwait.
- Human Limits: It included a sample of female students in the first and second year of university in the Social Science College at Kuwait University.
- Spatial boundaries: it included the Social Science College at Kuwait University.
- Time limits: The data was collected during the second semester of the academic year 2018/2019 from February until the end of May.

### Terminology of the study:

- **Obesity:** is a health condition with an excessive level of body fatness that increases the risk of morbidity and/ or mortality (WHO, 2000).

Obesity is defined as “a chronic complex disease defined by excessive adiposity that can impair health. It is in most cases a multifactorial disease due to obesogenic environments, psychosocial factors and genetic variants” (WHO, 2020).

### Methods:

#### - Sampling, recruitment, and ethics:

All participants gave informed written consent to participation and the study was approved by the University of Strathclyde Psychological and Health Sciences Ethics Committee. First and second-year Kuwait University, College of Social Science students were recruited to take part in this research between

February and May 2019. Sampling and recruitment have been described previously (Al Hammadi & Reilly, 2020). Briefly, all 1<sup>st</sup> and 2<sup>nd</sup> year Social Science undergraduates were requested to participate in this study. The inclusion criteria were: students should be female, Kuwaiti nationals, under 20.0 years old, and without any condition or illness which would have changed their weight status (e.g. pregnancy, long-bone fracture). Students were therefore excluded from participation if they were male, non-Kuwaiti nationals, aged 20 years old or more, or affected by the conditions indicated. The research invitation was sent by the College of Social Science to 2169 students, supplemented by brief presentations on the research over a period of a week; to invite students to participate in the research. In addition, posters were distributed in the faculty to help with recruitment. As a result, 525 students responded, and 400 students met the inclusion criteria as de-scribed previously (Al Hammadi & Reilly, 2020). All collected data were saved under the ID code, only the re-searcher was able to access that information (Al Hammadi & Reilly, 2020).

**- Measures of exposure (BMI defined obesity and high body fatness measured by bio-electrical impedance):**

Anthropometric measurements and BMI calculations were carried out as described by Al Hammadi and Reilly (2020). Briefly, Height to the nearest 0.1cm was measured by the Seca Stadiometer (Seca, London, England). Weight was measured without shoes to nearest 0.1kg for participants in light indoor clothing by the Tanita model TBF-310 (2625 South Clearbrook Drive Arlington Heights, Illinois 60005, USA).

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### **BMI measurements and definitions of obesity:**

Two BMI-based definitions of obesity were used in this study, to deal with differences in participant age, following Al Hammadi and Reilly (2020) and (WHO, 2019). A BMI z score of  $\geq 2.0$  relative to WHO 2007 (WHO, 2019) reference data was used to define obesity in the adolescents (17.0 to 19.0) years of age ( $n= 275$ ) and for those over 19.0 years old the adult cut off point of BMI  $\geq 30\text{kgm}^2$  was used to define obesity ( $n= 125$ ) (Al Hammadi & Reilly, 2020). In practice, the actual BMI values for the two definitions were similar: at age 18.5 years for example a BMI Z score of 2.0 is equivalent to a BMI of  $29.6\text{ kg/m}^2$ , and at 19.5 years of age the BMI cut-off which defined obesity was 30.0.

### **Body fat measurements and definitions of obesity:**

The method of measurement of body fatness and cut-offs for defining high body fatness were as described in our previous publication (Al Hammadi & Reilly, 2020):  $\geq 30\%$  of body weight as body fat defined high body fatness following previous studies which found substantially increased cardiovascular risk factors above this threshold (Rey-Lopez *et al.*, 2019; Reilly *et al.*, 2010; Chen *et al.*, 2018). The estimation of body fatness for participants was carried out by using the TANITA TBF-310 with the manufacturer's equation used to predict body fatness. The Tanita device was used as it is a practical option for body composition measurement in field studies of this kind (Williams *et al.*, 1992; Peterson *et al.*, 2016) e.g. is inexpensive and quick and painless. In addition, it has been established that the Tanita device has reasonable accuracy relative to reference methods in adolescents and young adults (Williams *et al.*, 1992; Peterson *et al.*, 2016). In this study, duplicate measurement of bioelectrical impedance was carried out for each participant and the mean of the

duplicates was calculated and used. All relative information related to students' age, height, clothes weight (standard weight of 1.0 kg) and sex were entered into the TANITA TBF-310 to obtain the body fatness estimate. Students were requested to fast at least 2 hours without food or drinks prior to the Tanita measurements.

### **Potential confounding variables:**

It seems unlikely that socio-economic status is a confounder of associations between obesity and educational or cognitive outcomes in Kuwait since obesity and socioeconomic status are not related in Kuwait or only related very weakly (Rey-Lopez *et al.*, 2019). In addition, our previous study in the same sample also showed that relationships between obesity and overall educational attainment were not confounded by socioeconomic status (Al Hammadi & Reilly, 2020). However, we considered student age and socio-economic status (paternal education) as potential confounders and so included them in analyses.

### **Cognitive function measurement:**

Al Ghatani *et al.*(2010) indicated that there is a need for a computerised Stroop Test in the Arabic language. Computerised tests of cognitive function are preferable to alternatives such as traditional pencil and paper tests because they are more practical, reliable and valid (Din *et al.*, 2019; Eide *et al.*, 2002; Van der Elst *et al.*, 2006). Therefore, we worked with the Brain Performance and Nutrition Research Centre (BPNRC) at Northumbria University in the UK to develop an Arabic Version of the SCWT, part of the Computerised Mental Performance Assessment System (COMPASS) Version 5.0 (Dodd *et al.*, 2015), modified with the help of the thesis author, and an Arabic language set of

instructions was added to make it easier for the participants to understand the SCWT (Dodd *et al.*, 2015). The present study is therefore the first research with the computerised SCWT in the Arabic language.

In the present study, we focused on using the SCWT to measure selective attention (the ability to suppress an automated/uninhibited response and focus attention) and response inhibition. These were operationalised by using the % of correct answers. Briefly, in our SCWT, words were presented on a laptop screen which were either 'congruent' (name of colour and colour of word the same) or 'incongruent' (name of colour and colour of word different). The words appeared randomly on the screen. Participants were asked to respond as quickly and as accurately as possible by using the trackpad on the laptop. Twenty tasks made up the SCWT- a series of colour names in Arabic appearing in different coloured fonts on the laptop screen, one by one. Participants were requested to use the trackpad on the laptop to match the colour font to the name of that colour. The words were presented in two different ways, with the colour name and colour the same (congruent) or different (incongruent). All the tasks were randomly presented. A pilot study was conducted on 19 participants to evaluate the feasibility of this test as well as to measure the duration of the test and also to refine the protocol.

### **Statistical analysis:**

Duplicate measures of BMI and Fat percentage were taken and mean of the data used in analysis. The data were analysed by using Medcalc and SPSS version 26. All data were tested for normality using the Kolmogorov-Smirnov (K-S) test in SPSS and the D'Agostino Pearson test in Medcalc. Descriptive data were provided as Mean (SD) or median (IQR) as appropriate; SCWT performance was not normally distributed (D'Agostino-Pearson Test, the data

were not normally distributed Skewness= -0.33 and Kurtosis = -0.46  $P < 0.0001$ ) and so was summarised as median (IQR), and the Mann Whitney U test was used to compare median performance on the SCWT between groups (the obese versus non obese and the high fat vs non high-fat). Differences in the distribution of Stroop test performance by obesity status and high body fatness status were also tested for significance using Chi-squared tests, with SCWT performance categorised by quartile (Q1-Q4 highest-lowest performance) as described previously (Hammadi et al., 2020) and the odds of being in the lowest quartile by obesity status (obese vs non-obese by BMI) and by fatness status (high body fatness vs healthy body fatness) were calculated, along with 95% CI. Reaction time data were normally distributed (D'Agostino-Pearson Test  $p=0.14$ , Skewness= 0.18 and Kurtosis = 0.34) and so have been summarised as mean (SD) and between-group differences tested for significance using independent sample t-tests.

The possibility that relationships between SCWT performance and both obesity status and fatness status were confounded by participant age or by socio-economic (parental education level) status was assessed using logistic regression as described in our previous publication (Al Hammadi & Reilly, 2020).

The power of the present study was unknown, and this study was considered exploratory research. The sample size of this study was larger than that of many previous studies which tested for associations between obesity and cognitive function though, for example the largest study included in a number of systematic reviews was 299 (Xu *et al.*, 2017; Reinert *et al.*, 2013; Farooq *et al.*, 2018; Cook *et al.*, 2017).

## Results:

### - Characteristics of study participants:

The participant characteristics are shown in Table 1. Of 525 potentially eligible participants, 400 fitted the inclusion criteria and completed the SCWT and also had BMI measures and body fatness estimates. The average of the age of the participants was 18.0 (SD 0.6) years, shown in Table 1.

Table (1)

Characteristics of participants in the study (n= 400, mean and SD except where noted)

Variables	Mean	SD
Age	18.0	0.6
BMI kg/m <sup>2</sup> median and range	27.5	15.1 to 50.2
Fat (%) median and range	32.0	5.1 to 54.0
Stroop Correct (%) answers, median and range	70	25th IQR = Q1 85-100 75th IQR = Q3 50-70 100th IQR = Q4 10-50
Response time (RT) milliseconds	2343	508

### - Stroop Colour Word Test (SCWT) performance and BMI defined obesity:

Stroop Test performance is summarised in Table 2. Median % correct answers in the sample with obesity defined by BMI (n= 163) was 60 (IQR 45-75) and in participants defined as not having obesity according to their BMI (n=237) median was 75 (IQR 55-90). The difference in median % correct answers between the group with obesity and the non-obese groups was significant (Mann Whitney U Test  $p < 0.001$ , shown in Table 2).

The odds ratio, unadjusted, for risk of being in the lowest quartile of Stroop Test performance for individuals with obesity according to BMI, was 2.05 (95% CI 1.30 – 3.25,  $P < 0.001$ ). The chi squared test on the distribution of SCWT by obesity status was also significant ( $P < 0.001$ ). Logistic regression results indicated that student age and parental educational attainment were not associated with obesity or with SCWT performance and did not confound the relationship between BMI defined obesity and Stroop Test performance.

#### **- Stroop Test performance and high body fatness:**

Stroop Test performance (median % correct answers) among those participants defined as having high body fatness ( $n = 247$ ) was 60 (IQR 46-80) and in the non-high fat ( $n = 153$ ) the median was 80 (IQR 60-90). The Mann-Whitney U test on differences in median % correct answers by high fatness versus non-high fatness was statistically significant ( $U = 14188$ ,  $Z = 4.2$ ,  $P < 0.001$ ; Table 2). The odds ratio, unadjusted, for risk of being in the lowest quartile of SCWT performance in the individuals with high fatness was 1.95 95% CI 1.19-3.22,  $P < 0.001$ ). The chi squared test on the differences in distribution of SCWT performance by body fatness was significant ( $P < 0.001$ ). Student age and parental educational attainment were not associated with fatness and with SCWT performance and did not confound the relationship between body fatness and SCWT performance, shown in Table 2.



Table (2)

Stroop Test performance quartiles by weight status & body fatness categories <sup>(\*)</sup>

Exposure variables	Number of Correct Answer (Stroop Test) n= 400				Total (n)
	Q1	Q2	Q3	Q4	
Non-Obese	74	70	47	46	237
With Obesity	26	30	53	54	163
Non-High Fat	52	47	27	27	153
With High Fat	48	53	73	73	247

<sup>(\*)</sup> Stroop correct answer range for each quartile as follows: Q1 85-100 (median 90); Q2 70-85 (median 80); Q3 50-70 (median 60); Q4 10-50 (median 35).

### Discussion:

This study is one of the very few that addressed the issue of the potential impact of obesity in the Gulf States beyond the usual impacts such as cardio-metabolic co-morbidities of obesity. Possible cognitive impacts of obesity are important because our previous systematic review showed that obesity in adolescents in the Gulf States is very prevalent (Boodai & Reilly, 2013), and it is well established that adult obesity is very prevalent in the Gulf States (Musaiger *et al.*, 2012; Elkum *et al.*, 2016; Elkum *et al.*, 2019; Rabeea *et al.*, 2019). However, some authors have argued that associations between obesity and cognitive function are still not clear and studies in western countries may have been confounded by socio-economic status (Santana *et al.*, 2017; Hill *et al.*, 2018), so there is a need for studies in countries where confounding of this kind is less of a problem. There is also a need for more studies which identify the specific cognitive processes which might be affected by obesity- the present

study aimed to expand our knowledge on specific cognitive impacts by examining associations of obesity with Stroop Test performance, a specific measure of selective attention and inhibition. Finally, the present study added to the literature by going beyond using the BMI as the measure of obesity- by adding a more direct and specific measure of body fatness as the exposure variable.

The present study indicated that being having BMI-defined obesity and/or having a high level of body fatness may impair performance on the Stroop Colour Word Test. A previous systematic review provided evidence that obesity is likely to impair some aspects of executive function in children and adolescents (Demos *et al.*, 2019), and another systematic review (Martin *et al.*, 2017) suggested that cognitive impairments associated with obesity might be more marked in females than in males. One study suggested that higher levels of visceral fat are associated with lower executive functioning in adolescents (Schwartz *et al.*, 2013). Some other studies have suggested that reducing body fatness might have cognitive benefits. For example, one study found that losing weight improves aspects of cognitive function in children (Walk *et al.*, 2020) (attentional inhibition, assessed using a modified version of the Eriksen flanker task) (Walk *et al.*, 2020).

The finding of a negative association between having obesity and specific measures of executive function supports our previous published results that obesity may impair academic attainment in Kuwaiti female university students (Al Hammadi *et al.*, 2020). The present study results may also help explain the findings of our previous study that educational attainment might be impaired by obesity. Reduced selective attention or reduced inhibition (present study) may contribute to reduced performance in educational assessments (Al Hammadi *et*

*al.*, 2020). However, further investigation is needed to have a clearer understanding as to how impaired cognition or educational attainment might arise from obesity-there are other potential mechanisms including increased absenteeism, poorer mental health, biological mechanisms (such as cognitive effects of inflammation) (Martin *et al.*, 2017; Preuss *et al.*, 2019); other mechanisms have also been suggested including stigmatisation and weight bias by teachers (Yokum *et al.*, 2012). Although different mechanisms have been investigated to understand the possible effect of obesity on cognition in human studies, animal models have also been used to explore the possible mechanisms further (Wan *et al.*, 2007). Animal studies have generally been supportive of the hypothesis that obesity impairs learning and cognitive processes related to learning (Wan *et al.*, 2007) which may be due to proinflammatory cytokine-dependent activation of glial cells (Wan *et al.*, 2007). The cardio-metabolic comorbidities of obesity can also impair cognitive processes. For example, Gluck *et al.* (2013) and Catoira *et al.* (2016), reported that impaired glucose metabolism may impair performance on the SCWT (Catoira *et al.*, 2016; Yokum *et al.*, 2012). Another study indicated an association between smaller brain volumes and higher BMI and % fat in adolescents (Reinert *et al.*, 2013). High body fatness may also affect brain blood flow which may impact cognitive functioning (McMorri, 2009).

One strength of the present study was that the setting in Kuwait meant that associations between obesity and cognitive processes could be tested relatively free of the problems of confounding by socioeconomic status. Studies in the western world which report poorer cognitive performance or poorer educational attainment in obese individuals find it hard to exclude the possibility that low socioeconomic status is re-sponsible, because low socio-economic

status is associated strongly with both obesity and poorer educational attainment in the western world. A second strength of the present study was that body fatness was measured, not just BMI, though in practice the results were similar whether obesity was defined as a high BMI or a high body fatness. The use of the Stroop Colour Word Test as our measure of cognitive function was also a strength- this is a reliable and valid measure of various cognitive processes (Scarpina & Tagini, 2017). A further strength of the present study was novelty- there are few such studies in adolescents or in young adults, and much of the research effort on the impact of obesity on cognitive function has focused on the elderly with an emphasis on cognitive ageing (Hou *et al.*, 2019). There are few studies of this kind from Arab states in general and the Gulf States in particular, and research of this kind may encourage greater effort at obesity prevention in the Gulf States in future, i.e. if it becomes clearer that obesity has cognitive effects in adolescence/early adulthood.

The present study also had a number of weaknesses. There was some evidence that reaction time was faster in the group with obesity (defined by BMI) but there was no evidence that reaction time was faster in the group with high body fatness, so whether or not reaction time was affected in the present study was unclear. Faster reaction time can reduce accuracy in test performance, so might have been an explanation of the lower test accuracy in the individuals with obesity in the present study. There is some previous evidence of faster reaction time among individuals with obesity in the literature (Farooq *et al.*, 2018), and this could indicate either faster cognitive processing or more impulsive responding (greater impulsiveness could be a cause or an effect of obesity and which might reduce the percentage of correct answers in the SCWT).

The present study focused only on the overall correct answers and overall reaction time, and not on the many other potential impacts of obesity on different cognitive processes (Scarpina & Tagini, 2017; Van der Elst *et al.*, 2006; Afsaneh *et al.*, 2012). Executive function includes other processes such as cognitive flexibility and memory performance; we were not able to measure those in this study and this restriction was practical. While it is difficult to compare Stroop Test results between different studies because of enormous variation in how testing is performed and scored (Afsaneh *et al.*, 2012), and because there has been limited use of Stroop Testing (SCWT) in Arab populations as noted above, the % correct answers in the present study may have been somewhat lower than expected, and the reaction times may have been somewhat slower than expected. Unpublished data from use of the COMPASS software Stroop Colour Word Test using a laptop with a mouse (no data are available with use of a trackpad as was used in the present study) in young English adults suggests that an (Afsaneh *et al.*, 2012) expected mean or median % correct answer score should be at least 70%- the median for the entire sample was 70% in the present study which would be considered a slightly low performance compared to a group of students in the UK. Typical (mean or median) reaction time from use of the COMPASS version of the Stroop Colour Word test in young English adults is around 991ms (Northumbria University, 2020), faster than in the present study. The present study was the first to use an Arabic version of the Stroop Colour Word Test and this particular version of the test may need refinement in future. In addition, participants could have been given more familiarization or practice with the tests before the data were collected in the present study- greater familiarization might have either improved the % correct answers, or the reaction time, or both. Participants did

not receive any practical training on how to use the laptop used to administer the test, and it may have taken them longer than expected to navigate the keyboard in order to click on the correct answer. This might have increased the reaction time and possible also reduced the test performance. A previous study reported a similar issue (Farooq *et al.*, 2018). It was the case that the reaction time in the first task of SCWT was consistently slower than that in the subsequent 19 tasks, and this might suggest that students needed to become more familiar with the test. However, test conditions were the same for all study participants and this should make a comparison between individuals with and without obesity appropriate.

### **Conclusion:**

This study suggests that having obesity, whether defined by BMI or high body fatness, may impair some aspects of cognitive function in Kuwaiti female students. Further research will be needed to examine the generalisability of these findings and to identify the underlying mechanisms of any effect of obesity on cognitive function.

### **Recommendations:**

Based on the findings of the current study, the researchers recommend the following:

- Increasing health awareness of the impact of obesity on educational attainment and cognition among university students and leaders.
- Improving the environment of the university and encouraging the healthy eating as well as the physical activity of students by providing separate facilities for males and females.

- It is necessary to collect more data on the association between obesity and education/cognition outcomes from the population of Kuwait and the Gulf using a larger sample size with a wider age range.

### **Suggested research:**

The researchers suggest conducting the following studies:

- Better study designs, such as randomised designs, that can deal with potential confounding are needed to study the effects of obesity on cognition outcomes.
- Longitudinal or intervention studies are warranted to test the causality between obesity and cognition and to investigate the mechanisms underlying this association.
- Mechanistic studies in animals and humans to explore mechanisms of obesity impact on brain function and structure.

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