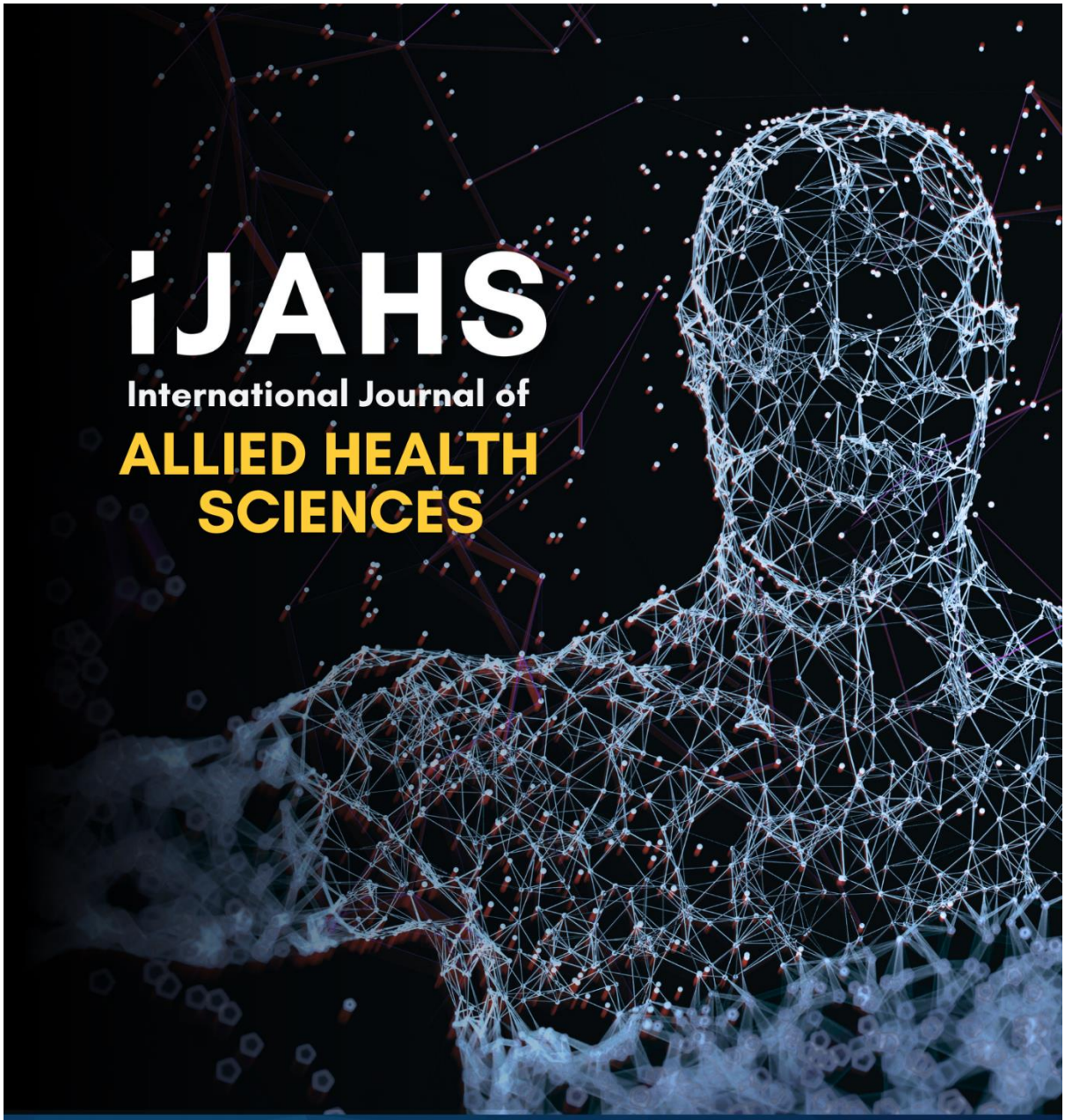

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Professorial lecture: Utilising Auditory Evoked Potentials for Interventions in Children with Autism

Auditory evoked potential (AEP) is a vital tool for audiologists worldwide. It is an objective measure of auditory function, capable of estimating an individual's hearing status and diagnosing disorders within the central auditory nervous system. The most common applications of AEP include estimating hearing thresholds, hearing screenings, and neuro-diagnostic evaluations. Less commonly, AEP is used to assess the effectiveness of interventions, predict outcomes of audiological treatments, or forecast the likelihood of certain disorders.

This lecture emphasized the use of AEP to evaluate the effectiveness of sound therapy and working memory interventions among children with autism spectrum disorder (ASD). Individuals with ASD often face sensory processing challenges, including auditory sensory gating deficits. These deficits can contribute to mental health issues such as anxiety, which in turn may affect emotional regulation (Jamal et al., 2025). The inaugural professorial lecture discussed strategies to address poor emotional regulation, highlighting the use of sound therapy combined with working memory training. Sound therapy is hypothesized to regulate brain function and address auditory sensory gating deficits, while working memory therapy aims to enhance inhibitory control, leading to improved emotional regulation and overall well-being in children with ASD.

The study's results were promising, demonstrating that AEP—specifically suppression otoacoustic emissions—showed significant positive changes following the sound and working memory therapy intervention. These changes indicate improvements in the neural inhibition system at the brainstem level. This suggests that the combined sound-working memory therapy has the potential to improve auditory sensory gating deficits and emotional regulation.

The optimal combination identified in the study involved white noise paired with working memory training, aligning with the principle of stochastic resonance (Söderlund, Sikström, & Smart, 2007).

The lecture also explored the future applications of AEP, particularly the auditory brainstem response (ABR) test, in predicting the likelihood of newborns developing ASD. This could potentially be achieved using existing ABR data collected through universal newborn hearing screening programs. Given the role of the auditory system in various disorders, it is hoped that audiologists will continue to provide expertise in sound therapy and AEP to support patient care and facilitate improved outcomes.

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ORIGINAL ARTICLE

Translation and Adaptation of Hyperacusis Questionnaire into Malay Language

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ABSTRACT

Background: A reduction in sound tolerance may result in considerable adverse effects for both the individual and their family. Individuals with limited tolerance may experience anxiety and fear when hearing such sounds, potentially leading to stress avoidance behaviours. Hyperacusis, defined by an excessive sensitivity to commonplace noises, can profoundly affect an individual's quality of life, resulting in anxiety or stress and avoidance of sound-dense surroundings. Standardized questionnaires, such as the Hyperacusis Questionnaire (HQ), are commonly used in clinical settings to assess and diagnose hyperacusis. Originally created in French and then translated into many languages, including English, Dutch, Swedish, and Japanese, the HQ allows clinicians to assess sound tolerance thresholds and the psychological impacts of hyperacusis. Despite the prevalence of hyperacusis in Malaysia, a validated Malay version of the HQ is not yet available. This situation poses challenges in accurately assessing and treating hyperacusis within the Malay-speaking population. The aim of this study is to translate and adapt the HQ into Malay. **Methods**: Translation process was conducted in 3 stages, including forward and backward translation, content and face validation, and reliability testing. In the translation phase, two bilingual translators independently performed forward translation from English to Malay, and two others conducted backward translation to English. Discrepancies were discussed and harmonized to produce a linguistically accurate Malay version. Content validation involved a panel of 7 experts who assessed item relevance, clarity, and cultural appropriateness using the Content Validity Index (CVI) . Reliability check was calculated with Cronbach Alpha on 103 participants **Results:** The item-level CVI (I-CVI) achieved a score of 0.83, while the scale-level CVI average (S-CVI/Ave) was 0.92, indicating strong content validity. For face validation, ten lay individuals evaluated the questionnaire's readability and cultural suitability, leading to minor modifications for enhanced clarity. Reliability testing was conducted with a sample of 103 participants from the target population, resulting in a Cronbach's alpha of 0.89, demonstrating high internal consistency. **Conclusion**: The findings suggest that the Malay version of the HQ is a valid, reliable, and culturally appropriate instrument for assessing hyperacusis.

INTRODUCTION

According to Baguley (2003), hyperacusis has been described as 'exceptional intolerance to common environmental sounds' and, alternatively, as 'consistently exaggerated or inappropriate responses to sounds that are neither dangerous nor unpleasantly loud to a typical person' (Journal of the Royal Society of Medicine, p.582) . Many classifications of hyperacusis have been proposed because of its subjectivity. According to Baguley (1995), the most basic classification divides the presentation into four categories: loudness, annoyance, pain, and fear. The impression of moderately powerful sounds as unbearably loud is known as loudness hyperacusis. Anger, anxiety and stress are the main symptoms of irritation hyperacusis, which is a negative emotional response. Avoidance actions are a symptom of fear hyperacusis, while stabbing pain in the ear is a symptom of pain hyperacusis. All cases of hyperacusis are bilateral in nature (Coey & Orlando, 2023).

The pathophysiological mechanism that may explain this aberrant reaction during stress involves the release of endogenous dynorphins into the synaptic area beneath the inner hair cells. As a result of this mechanism, glutamate neurotransmitter activity is increased, resulting in excessive loudness of perceived sound (Fioretti, Tortorella, Masedu, Valenti, Fusetti & Pavaci, 2015). To assess reduced tolerance, an individual's subjective description of discomfort is the primary factor in the diagnosis. Due to its subjectivity and often associated with other diseases, those who have hyperacusis may not receive a prompt diagnosis. This delay may increase the severity of their pain and complicate the treatment of the illness. In fact, a study has shown that continuous exposure

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to extreme high-frequency noise causes hyperacusis as one of their main discoveries (Radziwon, Auerbach, Ding, Liu, Chen & Salvi, 2019).

A decline ability to endure sounds may cause significant negative consequences to the individual as well as their family (Baguley, 2014). The auditory landscapes are rapidly evolving in the modern era. With modernization, diverse types of sounds which were rarely reverberated previously, have emerged and are becoming typical sounds that we hear every day such as the sound of traffic, trains, lawn mowers and phone ringing. When someone with low tolerance hears such noises, it may trigger their fear and anxiety, which could involve avoiding stressful situations. Clinical evidence suggests that some patients with hyperacusis experienced sound-induced ear pain, which manifests as a burning sensation in the ear (Baguley, 2014).

Currently, hyperacusis cannot be measured objectively without any participation from patient (Am Alkharabsheh & Alaqrabawi, 2021). In a clinical setting, hyperacusis is assessed using questionnaires and the uncomfortable loudness level (ULL) test (Am Alkharabsheh & Alaqrabawi, 2021). According to their study, patients who report having reduced tolerance to certain sounds usually have lower ULLs than 90 dB HL. To date, a few validated questionnaires have been published in English literature to help distinguish patients with hyperacusis from the general population. These include the multiple activity scale for hyperacusis (MASH) (Dauman & Bouscau-Faure, 2005), the hyperacusis questionnaire (HQ) created by Khalfa (Khalfa, Dubal, Veuillet, Perez-Diaz, Jouvent & Collet, 2002), and the questionnaire on cite (Am Alkharabsheh & Alaqrabawi, 2021). Among all existing questionnaires, the HQ is commonly used to detect and assess hyperacusis. The Hyperacusis Questionnaire (HQ) is a standardized self-assessment instrument utilized in clinical settings to assess an individual's tolerance to typical everyday sounds (Khalfa et al., 2002). It encompasses questions that focus on evaluating emotional, social, and functional reactions to sound, facilitating the identification of the degree of distress that results from sound sensitivity. Responses are frequently evaluated to categorize the severity of hyperacusis, assisting clinicians in diagnosis and management. The HQ has been translated into many different languages to effectively serve different population demographics. Despite initially created in French, the original report included an English translation. Until recently, the English version of the HQ has been the basis for other translations, including Dutch, Swedish and Japanese (Am Alkharabsheh & Alaqrabawi, 2021).

However, the Malay version is yet available. This study aims to close a significant gap in the field of auditory research by translating and validating a Malay version of the Hyperacusis Questionnaire that is culturally and linguistically appropriate, that can be used in audiology clinic in the future. Therefore, it is a need to establish a standardized tool that can accurately diagnose and treat hyperacusis in the Malay-speaking population.

MATERIALS AND METHODS

Study Design

This study was conducted using a cross-sectional approach (Forogh Karimipur Davaninezhad, 2009). The data was collected at one point in time using a questionnaire. This study intended to translate, measure the validity and reliability of Malay version of Hyperacusis Questionnaire (HQ-M). The questionnaire was given to qualified translators for the translation process, before being handed out to the panels for the content validation assessment and subsequently distributed to the laypeople from various occupation and education backgrounds for face validation and reliability tests. This research has been reviewed and approved by the IIUM Research Ethics Committee (IREC). All subjects' details and information were kept confidential.

Study Population and Sample Size

Four translators were involved in the translation process: two translators for forward and two translators for backward translation. For forward translation, the translators were selected based on these criteria; (i) possess the audiological knowledge; (ii) good grasp in both Malay and English language; and (iii) fulfil IIUM English Test up until level 5, or score band 6 and above for International English Language Testing System (IELTS). For the backward translation, the translators were selected based on these criteria; (i) blinded to the existence of the original Hyperacusis Questionnaire (HQ); and (ii) possess the Bachelor of Education with Honours in Teaching English as a Second Language (TESL). Neither must not know the original version of the instrument's intent to avoid information bias (Guillemin, Bombardier & Beaton, 1993).

In the reviewed process of the forward and backward translation, the expert committees which consists of three individuals with vast knowledge on Audiology were set up. This expert committee overseen the questionnaires to review and detect any discrepancies on the items. Next, seven panels were recruited in the content validity stage. These panels qualifications are (i) can read and understand Malay; (ii) an audiologist, speech therapist or a

questionnaire expert; and (iii) possess the knowledge of hyperacusis. In the face validity stage, ten laypeople from various occupations and education backgrounds were involved. The reliability test was conducted on 103 adults' participants who have concerns with their reduce tolerance towards normal daily sounds level. The sample size of at least 50 is sufficient to assess the reliability of a translated questionnaire, particularly using Cronbach's alpha (Bujang, Omar & Baharum, 2018). However, larger sample sizes are often preferred to ensure stable reliability results. The 103 participants who met both criteria were asked to fill up the questionnaire (HQ-M) based on their daily experience, and the scores will be analysed with Cronbach's alpha for reliability check.

Sampling Method

This study used purposive and convenience sampling techniques across the phases as respondents participated based on their convenient accessibility and proximity to the research. The samples were chosen according to their availability and capacity to participate in the study, along with the inclusion and exclusion criteria. The subjects were recruited through e-advertisement blasted in social media such as linked-in and Facebook where individuals who volunteered were asked to answer the questionnaire in the online platform.

Instrumentation

The English version of the Modified Khalfa Hyperacusis Questionnaire (Khalfa, 2002) was used as the main item in this study. The questionnaire consists of twenty items with functional, social, and emotional dimensions. The response for this questionnaire is using a scale of a three-point scoring system with the options being "no" (scoring 0 point), "sometimes" (scoring 2 points), to "yes" (scoring 5 points) (Am Alkharabsheh & Alaqrabawi, 2021). It was interpreted as 0-10 (normal), 12-40 (mild), 42-60 (moderate) and 62-100 (severe) (Maqbool, Deekshith & Hemaraja, 2022).

Study Procedure

Translation Process

The translation process followed by forward-backward method suggested by the Guillermin's guidelines (Guillemin, Bombardier & Beaton, 1993) for translation as summarized in the Figure 1.

Forward Translation and Reconciliation

Both translators were asked to translate the questionnaire to Malay independently and produced two initials Malay instrument HQ(M1) and HQ(M2). The translators then discussed together with the researcher and compiled both HQ(M1) and HQ(M2). Since both translators lived in different states, the discussion was mediated by the researcher through email conversations. The compiled version of HQ was finalized by assessing word ambiguities and inconsistencies. Amendments were made by the researcher with the consensus of both translators (Beaton, Bombardier, Guilllemin & Ferraz, 2000). The result of the forward translation produced the Harmonized HQ-M, HQ(M-H).

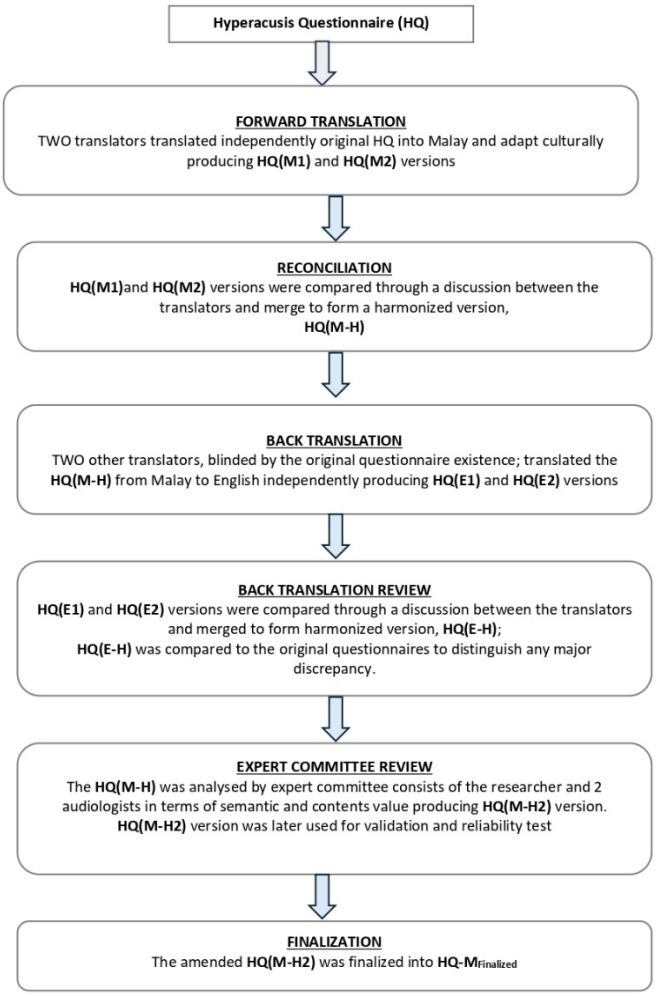

Figure 1: Graphic presentation of the flowchart of the translation and adaptation conducted for HQ

Backward Translation and Review

Another two translators were asked to back-translate the HQ(M-H) into original language independently, producing HQ(E1) and HQ(E2). Then, comprehensive review and discussion were mediated by the researcher where amendments and edits were made as needed with consensus of both translators (Beaton et al., 2000), to produce a harmonized back-translated instrument. The wording and language flow were reviewed by both translators were via email conversations, before being finalized into the Harmonized English HQ-M, HQ(E-H).

Expert Committee Review

The original instrument and the harmonized backward translation, HQ(E-H) were then compared to detect discrepancies. The researcher with another two experts in audiology were responsible to review all the items based on a few categories; no changes in words, changes in words but do not affect meaning, changes in words that may affect meaning and total changes in words. Then, the word or sentence was either maintained, or amended based on the committees' comments, including adding, omitting and changing terms. Another version of Harmonized HQ-M, HQ(M-H2) was then created following expert reviews' recommendations.

Content Validity

Seven panels were recruited in this study. All panels that fulfil the inclusion criteria involved for this stage were asked to rate the relevancy of HQ(M-H2)in terms of the readability, clarity, and suitability of the item in the cultural context. The 4-likert scale was used; 1-irrelevant, 2-quite relevant, 3-relevant, 4-very relevant. Content Validity Index (I-CVI) at item level and at scale level (S-CVI) was calculated using formula that will be further explain in the results section. The panels were also asked to give some remarks or recommendations for improvement of the items. Finally, the researcher reviewed each comment given and amended the items based on the panels' recommendations if necessary and relevant.

Face Validity

A face validity form was distributed to ten lay people that come from various occupations and education backgrounds. They were asked whether all the items in HQ(M-H2) were based on the suitability of the item to be asked, the readability of the sentence, the proper sentence structure and word choice. This process was evaluated using 'YES' or 'NO' answers. The subjects were also asked if they have any comments for any modifications.

Reliability

Reliability check was done in this study to measure the internal consistency of the HQ-$M_{Finalized}$ by analysing how well the items fit each other conceptually. The internal consistency between items in each scale was evaluated with Cronbach's Alpha to determine the questionnaire stability and responses' reliability within the given domain (Bujang, Omar & Baharum, 2018). This is to ensure that the items that measure the same construct formulate the corresponding scores. Analysis of the questionnaire reliability was conducted using SPSS 20. The final version of the Malay Hyperacusis Questionnaire or HQ-$M_{Finalized}$ has been labelled as HQ-M.

RESULTS

Translation Process

The forward translation, backward translation, and harmonized version of forward and backward translation following expert review. Changes were made to some of the items with experts' recommendations were compiled in Table 1.

Table 1: Original HQ, HQ(M-H), HQ(E-H), HQ(M-H2) and HQ-$M_{Finalized}$ following expert reviews

Item	Original HQ	HQ(M-H)	HQ(E-H)	HQ(M-H2)	HQ-$M_{Finalized}$
1.	Do you have trouble concentrating in a noisy or loud environment?	Adakah anda menghadapi masalah untuk menumpukan perhatian dalam persekitaran yang berbunyi bising dan kuat?	Are you having difficulty concentrating in a noisy and loud environment?	Adakah anda menghadapi masalah untuk menumpukan perhatian dalam persekitaran yang berbunyi bising dan kuat?	Adakah anda menghadapi masalah untuk menumpukan perhatian dalam persekitaran yang berbunyi bising dan kuat?
2.	Do you have trouble reading in a noisy or loud environment?	Adakah anda menghadapi masalah untuk membaca dalam persekitaran yang bising dan kuat?	Are you having difficulty reading in a noisy and loud environment?	Adakah anda menghadapi masalah untuk membaca dalam persekitaran yang bising dan kuat?	Adakah anda menghadapi masalah untuk membaca dalam persekitaran yang bising dan kuat?

3.	Do you ever use earplugs or earmuffs to reduce your noise perception? (Do not consider the use of hearing protection during abnormally high exposure situations)	Adakah anda pernah menggunakan penyumbat atau penutup telinga untuk mengurangkan bunyi bising? (Tidak termasuk penggunaan alat pelindung pendengaran semasa situasi bising yang luar biasa)	Do you ever use earplugs or earmuffs to reduce the loud noise? (Does not include the use of hearing protection devices during exceptionally noisy situations)	Adakah anda pernah menggunakan penyumbat atau penutup telinga untuk mengurangkan persepsi hingar? (Tidak termasuk penggunaan alat pelindung pendengaran semasa situasi bising yang luar biasa)	Adakah anda pernah menggunakan penyumbat atau penutup telinga untuk mengurangkan persepsi persekitaran terlalu bising? (Tidak termasuk penggunaan alat pelindung pendengaran semasa situasi bising yang luar biasa)
4.	Do you find it harder to ignore sounds around you in everyday situations?	Adakah anda berasa semakin sukar untuk tidak menghiraukan bunyi-bunyian di sekeliling anda setiap hari?	Do you find it increasingly difficult to ignore the noises around you everyday?	Adakah anda berasa sukar untuk mengabaikan bunyi-bunyian di sekeliling anda setiap hari?	Adakah anda berasa sukar untuk mengabaikan bunyi bising di sekeliling anda setiap hari?
5.	Do you find it difficult to listen to speaker announcements (such as airports, airplanes, trains, etc.)?	Adakah anda mengalami kesukaran untuk mendengar pengumuman dari pembesar suara (seperti di lapangan terbang, kapal terbang, kereta api, dll.)?	Do you have difficulty hearing announcements from loudspeakers? (e.g. at the airports, on airplanes, trains, etc.)	Adakah anda mengalami kesukaran untuk mendengar pengumuman dari pembesar suara (seperti di lapangan terbang, kapal terbang, kereta api, dan lain-lain)?	Adakah anda mengalami kesukaran untuk mendengar pengumuman dari pembesar suara (seperti di lapangan terbang, di dalam kapal terbang dan di dalam kereta api)?
6.	Are you particularly sensitive to or bothered by street noise?	Adakah anda agak sensitif atau terganggu dengan bunyi-bunyian di jalan raya?	Are you somewhat sensitive or easily bothered by road noises?	Adakah anda agak sensitif atau terganggu dengan bunyi-bunyian di jalan raya?	Adakah anda sensitif atau mudah terganggu dengan bunyi-bunyian di jalan raya?
7.	Do you “automatically” cover your ears in the presence of somewhat louder sounds?	Adakah anda secara spontan menutup telinga sejurus mendengar bunyi yang agak kuat?	Do you spontaneously cover your ears when you hear loud noises?	Adakah anda secara spontan menutup telinga apabila mendengar bunyi yang agak kuat?	Adakah anda secara spontan menutup telinga apabila mendengar bunyi yang agak kuat?
8.	When someone suggests doing something (going out, to the cinema, to a concert, etc.), do you immediately think about the noise you are going to put up with?	Apabila seseorang mencadangkan untuk melakukan sesuatu aktiviti (seperti keluar bersiar-siar, menonton wayang, konsert, dsb.), adakah anda serta-merta terfikirkan kebisingan bunyi yang bakal anda hadapi?	When someone suggests doing an activity (e.g. going out for a walk, watching a movie, attending a concert, etc.), do you immediately think of the noise you might encounter?	Apabila seseorang mencadangkan untuk melakukan sesuatu aktiviti (seperti keluar bersiar-siar, menonton wayang, konsert, dan lain-lain), adakah anda serta-merta terfikirkan kebisingan bunyi yang bakal anda hadapi?	Apabila seseorang mencadangkan untuk melakukan sesuatu aktiviti (seperti keluar bersiar-siar, menonton wayang dan konsert), adakah anda serta-merta terfikirkan kebisingan bunyi yang bakal anda hadapi?

9.	Do you ever turn down an invitation or not go out because of the noise you would have to face?	Adakah anda pernah menolak pelawaan untuk tidak keluar kerana risaukan bunyi bising yang bakal anda hadapi?	Have you ever declined an invitation to go out because of the noise you are about to encounter?	Adakah anda pernah menolak pelawaan untuk tidak keluar kerana risaukan bunyi bising yang bakal anda hadapi?	Adakah anda pernah menolak pelawaan untuk keluar kerana risaukan bunyi bising yang bakal anda hadapi?
10.	Do you find the noise unpleasant in certain social situations (e.g., nightclubs, pubs or bars, concerts, fireworks displays, cocktail receptions)?	Adakah anda mendapati bunyi bising di sesetengah aktiviti sosial tidak menyenangkan (cth, kenduri, majlis keramaian, konsert, pertunjukan bunga api, dsb.)?	Do you find the loud noise in certain social activities unpleasant? (e.g. gatherings, concerts, fireworks display, etc).	Adakah anda mendapati bunyi bising di sesetengah aktiviti sosial tidak menyenangkan (seperti kenduri, majlis keramaian, konsert, pertunjukan bunga api, dan lain-lain)?	Adakah anda mendapati bunyi bising di sesetengah aktiviti sosial tidak menyenangkan (seperti, kenduri, konsert dan pertunjukan bunga api)?
11.	Has anyone you know ever told you that you tolerate noise or certain kinds of sounds badly?	Adakah sesiapa pernah mengatakan bahawa toleransi anda terhadap bunyi bising atau bunyi tertentu adalah sangat teruk?	Has anyone ever said that your tolerance for loud or certain sounds is really poor?	Adakah sesiapa yang anda kenali pernah mengatakan bahawa toleransi anda terhadap bunyi bising atau bunyi tertentu adalah sangat rendah?	Adakah sesiapa yang anda kenali pernah mengatakan bahawa toleransi anda terhadap bunyi bising atau bunyi tertentu adalah sangat rendah?
12.	Are you particularly bothered by sounds others are not?	Adakah anda berasa terganggu dengan sesuatu bunyi yang tidak menjadi gangguan kepada orang lain?	Do you feel bothered by a sound that does not bother others?	Adakah anda berasa terganggu dengan sesuatu bunyi yang tidak menjadi gangguan kepada orang lain?	Adakah anda berasa terganggu dengan sesuatu bunyi yang tidak menjadi gangguan kepada orang lain?
13.	Are you afraid of sounds that others are not?	Adakah anda berasa takut atau gusar pada sesuatu bunyi yang tidak menjadi masalah kepada orang lain?	Do you feel afraid or anxious by a sound that is not a problem to others?	Adakah anda berasa takut pada sesuatu bunyi yang tidak menjadi masalah kepada orang lain?	Adakah anda berasa takut pada sesuatu bunyi yang tidak menjadi masalah kepada orang lain?
14.	Do noise and certain sounds cause you stress and irritation?	Adakah bunyi bising dan bunyi tertentu menyebabkan anda berasa tertekan dan jengkel?	Do loud and certain sounds make you feel stressed and annoyed?	Adakah bunyi bising dan bunyi tertentu menyebabkan anda berasa tertekan dan rengsa?	Adakah bunyi bising dan bunyi tertentu menyebabkan anda berasa tertekan dan tidak senang?
15.	Are you less able to concentrate in noise toward the end of the day?	Adakah kemampuan anda untuk menumpukan perhatian dalam suasana bising semakin berkurangan menjelang penghujung hari?	Does your ability to concentrate in a noisy environment decline towards the end of the day?	Adakah kemampuan anda untuk menumpukan perhatian dalam suasana bising semakin berkurangan menjelang penghujung hari?	Adakah kemampuan anda untuk menumpukan perhatian dalam suasana bising semakin berkurangan menjelang penghujung hari?

16.	Do stress and tiredness reduce your ability to concentrate in noise?	Adakah tekanan dan keletihan mengurangkan kemampuan anda untuk menumpukan perhatian dalam persekitaran yang bising?	Does stress and fatigue reduce your ability to focus in a noisy environment?	Adakah tekanan dan keletihan mengurangkan kemampuan anda untuk menumpukan perhatian dalam persekitaran yang bising?	Adakah tekanan dan keletihan mengurangkan kemampuan anda untuk menumpukan perhatian dalam persekitaran yang bising?
17.	Do you find sounds annoy you and not others?	Adakah anda berasa rimas pada bunyi-bunyian yang tidak merimaskan untuk orang lain?	Do you feel irritated by sounds that are not bothering others?	Adakah anda berasa jengkel pada bunyi-bunyian yang tidak menjengkelkan untuk orang lain?	Adakah anda berasa jengkel pada bunyi-bunyian yang tidak menjengkelkan untuk orang lain?
18.	Are you emotionally drained by having to put up with all daily sounds?	Adakah anda berasa keletihan emosi kerana perlu menghadapi bunyi-bunyian dalam kehidupan seharian?	Do you feel emotionally exhausted from dealing with noises in your everyday life?	Adakah kemampuan anda untuk menumpukan perhatian dalam suasana bising semakin berkurang menjelang penghujung hari?	Adakah anda berasa keletihan emosi kerana perlu menghadapi bunyi-bunyian dalam kehidupan seharian?
19.	Do you find daily sounds having an emotional impact on you?	Adakah anda mendapati bunyi-bunyian seharian memberi kesan emosi kepada anda?	Do you find that everyday sounds have an emotional impact on you?	Adakah anda mendapati bunyi-bunyian seharian memberi kesan emosi kepada anda?	Adakah anda mendapati bunyi-bunyian seharian memberi kesan emosi kepada anda?
20.	Are you irritated by sounds others are not?	Adakah anda berasa jengkel dengan sesuatu bunyi yang tidak menjengkelkan kepada orang lain?	Do you feel annoyed by sounds that are not annoying to others?	Adakah anda berasa terganggu dengan sesuatu bunyi yang tidak merengsakan kepada orang lain?	Adakah anda berasa tidak senang dengan sesuatu bunyi yang tidak menjadi masalah kepada orang lain?

Table 3: Changes in semantics and word choice

Item	HQ(M-H2)	HQ-M$_{Finalized}$	Changes		Justifications
			From	To	
3	Adakah anda pernah menggunakan penyumbat atau penutup telinga untuk mengurangkan persepsi hingar? (Tidak termasuk penggunaan alat pelindung pendengaran semasa situasi bising yang luar biasa)	Adakah anda pernah menggunakan penyumbat atau penutup telinga untuk mengurangkan persepsi persekitaran terlalu bising? (Tidak termasuk penggunaan alat pelindung pendengaran semasa situasi bising yang luar biasa)	hingar	persekitaran terlalu bising	The word '*hingar*' may be difficult to be understood for some speakers.
6	Adakah anda agak sensitif atau terganggu dengan bunyi-bunyian di jalan raya?	Adakah anda mudah sensitif atau terganggu dengan bunyi-bunyian di jalan raya?	agak	mudah	In the original HQ, the word 'particularly' is used. '*mudah*' was decided to be more suitable in this context which to emphasize the sensitivity

14	Adakah bunyi bising dan bunyi tertentu menyebabkan anda berasa tertekan dan rengsa?	Adakah bunyi bising dan bunyi tertentu menyebabkan anda berasa tertekan dan tidak senang?	rengsa	tidak senang	The word *'merengsakan'* may be difficult to be understood for some speakers.
20	Adakah anda berasa tidak menyenangkan dengan sesuatu bunyi yang tidak merengsakan kepada orang lain?	Adakah anda berasa tidak senang dengan sesuatu bunyi yang tidak menjadi masalah kepada orang lain?	terganggu, merengsakan	tidak senang, tidak menjadi masalah	The word *'merengsakan'* is difficult to understand especially for the public and '*tidak senang'* was used to fit the correct meaning of the question

Content Validation

The content validity was determined based on the viewpoint of seven panels on the HQ(M-H2). It was calculated using two forms of validity index which were item (I-CVI) and scale-level (S-CVI). The recommended item level content validity index (I-CVI) score that was considered excellent is 0.78 or higher (Shi et al., 2021). An item with a score of 3 or 4 was deemed relevant and equal to value 1, while an item with a score of 1 or 2 was deemed irrelevant which equal to value 0. The I-CVI was calculated using equations below (Saiful, 2019).

Equation for I-CVI:

$$I-CVI = \frac{The\ sum\ of\ relevant\ rating\ given\ by\ panels\ for\ each\ item}{The\ number\ of\ panels}$$

Equation for S-CVI/Ave:

$$S-CVI = \frac{The\ sum\ of\ I-CVI\ scores}{Total\ number\ of\ items}$$

Table 2: I-CVI for 20 Items

Items	I-CVI
1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18	1.0
2, 6, 17	0.86
19, 20	0.71

Scale level content validity index (S-CVI) was calculated by the average of the I-CVI scores for all items on the scale (S-CVI/Ave), calculation shown as follows. The acceptable value for S-CVI/Ave was recommended of 0.9 or higher (Shi et al., 2021). The obtained value in this study was 0.95, which is over the acceptable value.

During this stage, panels made recommendations on the semantics (study of meaning) and words choice to ensure their suitability with the target population. All stated as Table 3.

Face Validation

In this process, all ten panels voted 'YES' for all the items in the HQ-$M_{Finalized}$ which indicates that the panels find the translated items clear, culturally appropriate, and understandable. The items were improved based on the suggestions to allow better understanding of the questionnaire. The finalized version of HQ-M shown in Appendix I.

Reliability

The internal consistency reliability was determined by using Cronbach's Alpha in which the α-value of at least 0.78 or higher was considered acceptable (Shi, Mo & Sun, 2021). However, a small number (close to 0) indicates that some or all the items are not measuring the same dimension (Bujang et al., 2018). The α-value for the HQ-M was 0.898, suggests good reliability in measuring the same thing in the item. Table 4 shows Cronbach's Alpha value for each item if each one of them was deleted.

DISCUSSION

In this study, the primary objective is to provide a final output that maintains meaning, is comprehensible to the intended audience and accurately captures any detail in the source and target language (Hall, Zaragoza & Hamdache, 2017). In the translation process, some of the words from the forward translation were changed in harmonized forward-backward translation after the researcher found the word discrepencies. For example, the word 'automatically' in item 14 was forward-translated as '*secara spontan'* which was translated back to English by backward translator as 'spontaneously'. According to *Dewan Bahasa dan Pustaka Edisi Keempat* (2005), the

word 'automatic' means something that moves by itself that mostly referred to machines.

Table 4: Cronbach's Alpha if item deleted

Item	Cronbach's Alpha if item deleted
1	0.894
2	0.899
3	0.894
4	0.892
5	0.897
6	0.890
7	0.899
8	0.891
9	0.893
10	0.894
11	0.896
12	0.892
13	0.896
14	0.890
15	0.891
16	0.893
17	0.888
18	0.888
19	0.887
20	0.889

While 'spontaneous' is more suitable to describe human's behavior which done without thoughts or intention. The choice of word is crucial during the translation process to avoid misinterpretation of the item. For example, the examples of social situations in item 10 were changed according to cultural appropriateness. 'Nightclubs, pubs or bars, cocktail receptions' were changed to '*kenduri, majlis keramaian'*as it was more suitable in Malay culture context. Many of the items in the backward translation were structured differently but implied the same meaning as the original version. For example, in item 18, the sentence 'Are you emotionally drained by having to put up with all daily sounds?' became 'Do you feel emotionally exhausted from dealing with noises in your everyday life?' in which both carried the same meaning. It is acceptable if the sentence structure in the backward translation differs from the original form, if it conveys the same ideas and have the same effect on the reader (PacTranz, n.d.).

The result of this study showed only two items with I-CVI value of 0.71, which according to Lynn (1986), acceptable CVI value when six to eight experts were involved should be at least 0.83. However, according to Zamanzadeh, Ghahramanian, Rassouli, Abbaszadeh, Alavi-Majd & Nikanfar (2015), items with I-CVI values 0.7 to 0.79 need to be revised, while items with I-CVI values less than 0.7 need to be eliminated. Therefore, the items were improved following suggestions from the panels to improve the questionnaire and their comments were addressed. S-CVI/Ave of this instrument scored a 0.95 which was above the acceptable value. This suggested that the contents were highly relevant to represent the measured outcome and the target population (Liong, Sie, Lau, Saiful, Yusoff, Lee, Choi, Rashid, Wahid & Xiao, 2017). During face validation, there was not much modification made as most of them agreed that all items appear to flow logically in terms of grammar, syntax, organization, appropriateness and literally the validity of the measurement procedure as recommended by Liong et al. (2017). For internal consistency, our results showed that the Bahasa Malay version of questionnaire had high internal consistency. The overall Cronbach's Alpha of the HQ-$M_{Finalized}$ or finally labelled as HQ-M was 0.898, was considered statistically acceptable. Cronbach's Alpha varied between 0.887 and 0.899 when each one of the 20-items was deleted implying every item is equally important in the instrument as shown in Table 4.

There are several limitations to this study, including the complexity of translating between English and Malay. Some English words have multiple Malay equivalents, creating ambiguity that requires clarifications to from translators throughout the process. Additionally, the purposive and convenience sampling method which involves selecting participants based on their accessibility and willingness to participate, can limit research findings as it may not accurately represent the broader population. Hence, lacking in generalizability and subsequently limiting the applicability of findings to wider, more diverse groups. Future research would benefit from a larger sample size that includes all races in Malaysia for more comprehensive psychometric analysis. Using HQ-M in clinical settings with patients exhibiting hyperacusis symptoms, even if they are unaware of the condition, can help clinicians raise awareness and provide targeted assistance to Malaysian patients suffering from this problem.

CONCLUSION

The findings of this study showed that the Malay version of HQ is valid, reliable, simple, easy to understand and use for the assessment of hyperacusis in Malay-speaking populations. The future direction of study will be to psychometrically evaluate the severity level of HQ scoring.

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APPENDIX 1

THE MALAY HYPERACUSIS QUESTIONNAIRE (HQ-M)

Tandakan (√) pada ruangan "**YA**", "**KADANG-KADANG**", atau "**TIDAK**" mengikut pengalaman seharian anda.

Item	**Soalan**	**YA (5m)**	**KADANG-KADANG (2m)**	**TIDAK (0m)**
1	Adakah anda menghadapi masalah untuk menumpukan perhatian dalam persekitaran yang berbunyi bising dan kuat?			
2	Adakah anda menghadapi masalah untuk membaca dalam persekitaran yang bising dan kuat?			
3	Adakah anda pernah menggunakan penyumbat atau penutup telinga untuk mengurangkan persepsi persekitaran terlalu bising? (Tidak termasuk penggunaan alat pelindung pendengaran semasa situasi bising yang luar biasa)			
4	Adakah anda berasa sukar untuk mengabaikan bunyi bising di sekeliling anda setiap hari?			
5	Adakah anda mengalami kesukaran untuk mendengar pengumuman dari pembesar suara (seperti di lapangan terbang, di dalam kapal terbang dan di dalam kereta api)?			
6	Adakah anda sensitif atau mudah terganggu dengan bunyi-bunyian di jalan raya?			
7	Adakah anda secara spontan menutup telinga apabila mendengar bunyi yang agak kuat?			
	TOTAL MARKS FOR SUBSCALE **F**: _____			

Item	**Soalan**	**YA (5m)**	**KADANG-KADANG (2m)**	**TIDAK (0m)**
8	Apabila seseorang mencadangkan untuk melakukan sesuatu aktiviti (seperti keluar bersiar-siar, menonton wayang dan konsert), adakah anda serta-merta terfikirkan kebisingan bunyi yang bakal anda hadapi?			
9	Adakah anda pernah menolak pelawaan untuk keluar kerana risaukan bunyi bising yang bakal anda hadapi?			
10	Adakah anda mendapati bunyi bising di sesetengah aktiviti sosial tidak menyenangkan (seperti, kenduri, konsert dan pertunjukan bunga api)?			
11	Adakah sesiapa yang anda kenali pernah mengatakan bahawa toleransi anda terhadap bunyi bising atau bunyi tertentu adalah sangat rendah?			
12	Adakah anda berasa terganggu dengan sesuatu bunyi yang tidak menjadi gangguan kepada orang lain?			

13	Adakah anda berasa takut pada sesuatu bunyi yang tidak menjadi masalah kepada orang lain?			
			TOTAL MARKS FOR SUBSCALE **S**: _____	

Item	**Soalan**	**YA (5m)**	**KADANG-KADANG (2m)**	**TIDAK (0m)**
14	Adakah bunyi bising dan bunyi tertentu menyebabkan anda berasa tertekan dan tidak senang?			
15	Adakah kemampuan anda untuk menumpukan perhatian dalam suasana bising semakin berkurangan menjelang penghujung hari?			
16	Adakah tekanan dan keletihan mengurangkan kemampuan anda untuk menumpukan perhatian dalam persekitaran yang bising?			
17	Adakah anda berasa jengkel pada bunyi-bunyian yang tidak menjengkelkan untuk orang lain?			
18	Adakah anda berasa keletihan emosi kerana perlu menghadapi bunyi-bunyian dalam kehidupan seharian?			
19	Adakah anda mendapati bunyi-bunyian seharian memberi kesan emosi kepada anda?			
20	Adakah anda berasa tidak senang dengan sesuatu bunyi yang tidak menjadi masalah kepada orang lain?			
		TOTAL MARKS FOR SUBSCALE **E**: _____		

**12-40 (mild), 42-60 (moderate) and 62-100 (severe)

ORIGINAL ARTICLE

Development and Validation of a Tool to Facilitate Resilience and Good Mental Health: The My Sejahtera Ecology Map

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ABSTRACT

Background: There has been a growing body of research on the influence of social environment on mental well-being. Bronfenbrenner's Ecology Systems theory has proposed an extensive description of components and relationships of the social ecology of a person for their growth. However, there is a paucity of tools available for mental health professionals in implementing the theory within their practice. Therefore, this study aimed to develop and validate a tool to explore the social ecology of a person to aid understanding the influence of this on the state of mental well-being. **Methods:** This study developed instructions to draw and explore social ecology and established several validities evidence. Content validity used item-related content validity index employing five experts in psychiatry, psychology, and counselling to review the instructions for the tool. Face validity was established using a face validity index among ten working adults. Finally, criterion-related validity was established by improvement in mental health self-efficacy measured using the Mental Health Confidence Scale among 41 working adults. Descriptive analysis used frequency and percentage for categorical variables and mean and standard deviation for numerical variables. Inferential analysis used paired-sample t-test analysed on SPSS 29. **Results:** The My Sejahtera Ecology Map (MySEM) tool showed good content and face validity indices ranging from 0.80 to 1.00. Mental health self-efficacy showed significant improvement in optimism ($p < 0.05$) and factor coping ($p < 0.001$) after the MySEM activity. **Conclusion:** The tool has promising benefits in improving mental health self-efficacy through increasing factor-coping and optimism. The MySEM tool provided a standardised approach to apply the Bronfenbrenner's Ecology Systems theory for use by mental health professionals.

INTRODUCTION

A state of mental well-being allows a person to cope with life challenges, achieve their full potential, learn and work effectively, as well as be able to contribute to their community (WHO, 2022). Life experiences are dynamic with positive and negative events that can influence the state of mental health. A person should be equipped with flexibility and resources to adapt to the changes in order to maintain mental well-being. Both positive and negative experiences are opportunities for the person to grow psychologically, to achieve their full potential, to function effectively, and to contribute to their community. Providing insight into these experiences will empower the psychological growth of a person.

There has been a growing body of research on the influence of social environment on mental well-being. A longitudinal study among the Dutch population revealed that social environment changes were associated with mental health changes (Sui et al., 2023). Social support has also been reported to have a direct impact on life satisfaction and is partially mediated by mental well-being (Wang et al., 2023) and has become the target of intervention to improve mental well-being (Appleton et al., 2023).

Interestingly, the influence of social support on mental well-being has also shown mixed outcomes. Perceived social support has been shown to influence positively on mental well-being, but receiving support has mixed outcomes (Uchino et al., 2023). It seems the type of stressor, the profile of the support provider, and the support process played a vital role in contributing to a positive outcome.

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Appleton et al. (2023) have extensively described different sources and types of social support. Sources of support may come from mental health or social practitioners, topic experts, peers, and community members. Resources that are available to the person are contingent on their social connectedness. A person may receive concurrent support from different sources and, in some instances, receive concerted support from multiple sources. These sources may provide support in terms of information, care, assistance, and direct provision of solutions. This can lead to additional support being provided by government services, an improved personal agency and coping strategies, and improvement in resources in both the cause of stress and social inclusion.

On a theoretical basis, Bronfenbrenner's Ecology Systems theory has proposed an extensive description of components and relationships of the social ecology of a person for their growth. The theory has been applied to various contexts such as health education (Cala & Soriano, 2014), social-emotional problems (Vaezghasemi et al., 2023), and work retention (Neiterman et al., 2021). The theory explained a person being surrounded by several systems that consisted of microsystem, mesosystem, exosystem, and macrosystem (Newman & Newman, 2020).

The microsystem described the individual that often interacted with the person, thus directly influencing their state of mental well-being. The mesosystem describes the interaction between the different individuals surrounding a person (microsystem) and dynamically influences the person. The exosystem, on the other hand, describes the individual that interacts with the microsystem and is not directly involved with the person. The exosystem interactions, nevertheless, have an indirect impact on the person by altering how the individual in the microsystem behaves towards the person. Finally, macrosystem describes the external factors involving culture, policy, and law that dictate or shape the interaction and practices of the community.

Currently, there is a paucity of tools available for mental health professionals in implementing the theory within their practice. Mental health professionals that were familiar with theory may implement it in their perspective without standardisation in approach. Therefore, this study aimed to develop and validate a tool to explore the social ecology of a person to aid understanding the influence of social ecology on the state of mental well-being.

MATERIALS AND METHODS

This study consists of three phases, that are: (a) conceptual development and content validation, (b) pilot and face validation, and (c) criterion-related validation studies.

Conceptual Development & Content Validity

Conceptual development employed a narrative review methodology to define the components and use of the social ecology tool. Specific focus was placed on defining the components and ways to assess. The draft of the tool was sent for commentary and assessment for validity to five experts in psychiatry, counselling, and psychology. Amendments were made to the draft as appropriate and sent back to the expert reviewer for any additional comments.

Experts rated the relevance and clarity of the instructions and diagram on a scale from 1 to 4, representing "not relevant" or "not clear" to "very relevant" or "very clear". A response of 1 or 2 was recoded into 0, and 3 and 4 were recoded into 1. The average score was computed to derive the content validity index. An item-related content validity index (I-CVI) was computed for each instruction, and those scoring less than 0.80 were candidates for improvements. Feedback from experts on these instructions was sought as necessary.

Pilot & Face Validity Study

The tool was piloted on ten adult participants selected through convenience sampling and administered under guidance in a workshop setting. The participants followed the instructions narrated by a facilitator to draw their Sejahtera Ecology Map. The administration of the tool requires a trained facilitator following the set of questions provided and addressing questions from the participants.

Upon completion, the participants independently rated the face validity of the tool on a response scale ranging from 1 to 4 for ease of understanding, personal relevance, meaningfulness, and conciseness. Participants may provide comments, either written or verbally, to the facilitator. Such comments guided the amendments of the draft tool.

The four-point ordinal responses were dichotomised with "1" and "2" responses regarded as disagreement and "3" and "4" responses regarded as agreement, like recoding for I-CVI above. The proportion of agreements of more than 0.80 was considered to pass the item-related face validity index (I-FVI).

Criterion-related Validation Study

This phase employed methodology similar to content validity and attempted to assess the tool's impact on

mental health self-efficacy. This phase involved 41 working adults chosen using convenience sampling. Criterion-related validity was established as improvements in mental health self-efficacy.

Demographic information such as age, gender, education level, household income, and experience using mental health services was obtained. Mental health self-efficacy was measured two weeks before and immediately after participating in the MySEM activity.

Mental health self-efficacy was measured using the Mental Health Confidence Scale (Carpinello et al., 2000) translated into the Malay language, which consists of 15 items measuring three dimensions that are: (a) optimism, (b) factor coping, and (c) advocacy. The optimism and factor coping subdimensions have six items each. Whereas the advocacy subdimension has three items. The Malay instrument utilised a 6-point interval scale with the extremes defined as "very not confident" and "very confident", respectively. It has good content and construct validities as well as a 0.72 to 0.86 reliability index on Cronbach's alpha across the three subdimensions (Mohd Nazori et al., in press). Items can be scored by summation for each dimension or the whole construct. The optimism and factor coping subdimensions have scores ranging from 6 to 36, and the advocacy subdimension has scores ranging from 3 to 18. Therefore, the total score may range from 15 to 90 for the whole construct.

Descriptive analysis employed frequency and percentage for categorical variables and mean and standard deviation for numerical variables. A paired sample t-test was used to compare dimensions of mental health self-efficacy before and after utilising the Sejahtera Ecology Map.

Ethical approval was obtained from the IIUM Research Ethics Committee [IREC 2024-192].

RESULTS

There were five experts from psychiatry, counselling, and psychology who provided a review of the instructions for the My Sejahtera Ecology Map (MySEM) and a total of 51 participants involved in the face and criterion-related validation studies.

Content Validity

Initial content validity review revealed almost all instructions were relevant and clear (rating of 3 or 4), except for clarity on instructions to explore the mesosystem. Therefore, item-related CVI (I-CVI) ranged from 0.67 to 1.00. Some of the instructions that were scored relevant and clear were also given feedback on how to improve the instructions. Much of the feedback was related to improving instructions on microsystem and chronosystem for better clarity and ease.

This feedback was considered during the modification of the instructions. After modification, the instructions were reviewed and resulted in I-CVI ranging from 0.80 to 1.00. Table 1 below summarises the I-CVI for the initial and final instructions.

Table 1: Item-related Content Validity Index (N = 5)

Systems	Criteria	I-CVI	
		Initial	Final
The person	Relevance	1.00	1.00
	Clarity	1.00	1.00
Micro	Relevance	1.00	1.00
	Clarity	0.80	1.00
Meso	Relevance	1.00	1.00
	Clarity	0.67	0.80
Chrono	Relevance	1.00	1.00
	Clarity	0.80	1.00

Pilot and Face Validity

The final instructions were then piloted to 10 adults that rated the experience drawing and exploring the MySEM on ease of understanding, relevance, meaningfulness, and conciseness. The initial FVI ranged from 0.80 to 1.00. The pilot study participants also provided feedback on how the tool was relevant to their situation and how their experience in drawing and exploring their MySEM can be improved. All feedback was used to improve the experience by including additional material and providing a suitable environment for the activity.

Criterion-related Validity

The criterion-related validity was established using mental health self-efficacy involving 41 participants across three sessions. The multiple sessions were an improvement for the activity environment to allow better engagement between facilitators and participants and improve openness to discuss and explore their MySEM. On average, participants were 37.3 years old with at least one child. Most participants were female, in permanent employment, worked at least six years or more, were married, had at least an undergraduate certificate, and never received help from any mental health professionals.

The pre-measurement for mental health self-efficacy reported a mean total score of 64.3 points (SD = 10.42) with each subdimension reporting mean scores of 28.7, 21.8, and 13.8 points for optimism, factor coping, and advocacy, respectively. Meanwhile, the post-

measurement for mental health self-efficacy reported a mean total score of 70.2 points (SD = 16.51) with each subdimension reporting mean scores of 30.5, 25.8, and 14.0 points for optimism, factor coping, and advocacy, respectively. Comparatively, the mean total score was higher in post-measurement, with the most notable differences in the subdimensions of factor coping, optimism, and advocacy in descending order of magnitude. Table 2 below summarises the descriptive statistics for demographic characteristics and measures of mental health self-efficacy prior to and after the MySEM activity.

Table 2: Demographic Characteristics and Mental Health Self-Efficacy (N = 41)

Variable	*n* (%)	Mean (*SD*)
Age (years)		37.3 (7.31)
Gender		
Male	7 (17.1)	
Female	34 (82.9)	
Employment term		
Permanent	32 (84.2)	
Contract	6 (15.8)	
Years of service		
Less than 3 years	3 (7.7)	
3 – 5 years	4 (10.3)	
6 – 10 years	13 (33.3)	
More than 10 years	19 (48.7)	
Marital status		
Married	25 (65.8)	
Single	10 (26.3)	
Divorced	2 (5.2)	
Deceased spouse	1 (2.6)	
Number of children		1.6 (1.37)
Highest education		
Highschool certificate	3 (7.9)	
Diploma	21 (55.3)	
Degree	13 (34.2)	
Master	1 (2.6)	
Received mental health professional help		
None	28 (71.8)	
Yes	11 (28.2)	
Mental health self-efficacy (pre-test)		64.3 (10.42)
Optimism		28.7 (2.06)
Factor coping		21.8 (7.71)
Advocacy		13.8 (2.79)
Mental health self-efficacy (post-test)		70.2 (16.51)
Optimism		30.5 (5.19)
Factor coping		25.8 (9.20)
Advocacy		14.0 (4.32)

The measures of mental health self-efficacy were tested for significant differences using a paired-sample t-test. Analysis revealed significant differences in subdimensions of optimism [t(40) = -2.47, p = 0.018] and factor coping [t(40) = -5.21, p < 0.001], as well as the total score of mental health self-efficacy [t(40) = -6.03, p < 0.001]. The advocacy subdimension showed no significant difference (p = 0.332). Scores for optimism, factor coping, and total mental health self-efficacy were significantly higher after the MySEM activity, with mean differences of 1.3, 5.0, and 6.6 points, respectively.

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DISCUSSION

Scores reported were on moderate level among the British adult population (Swami et al., 2024) and among youths in Indonesia, Malaysia, and Thailand (Chusniyah et al., 2020). Male showed slightly higher mean scores of self-efficacy compared to female British adults despite showing no significant difference (Swami et al., 2024). Previous study on mental health self-efficacy showed positive correlation with various constructs such as positive self-belief and mental well-being (Swami et al., 2024). A study among youths in Indonesia, Malaysia, and Thailand reported mental health self-efficacy significantly correlated with positive mental health and subjective happiness (Chusniyah et al., 2020). Interestingly, youths in Malaysia reported significantly higher mental health self-efficacy compared to Thai and Indonesian youths. Geographical location and the sociodemographic background may play a role on the development of mental health self-efficacy among youths.

The level of self-efficacy was almost similar to the findings of this study. However, relationships and differences in mental health self-efficacy between the participants were not analysed. The small sample size, given the research objective and design of this study, did not allow for a robust and reliable analysis. Future research may seek to improve this by employing larger sample size using a cross-sectional or longitudinal design. The exploration of MySEM will develop insight into the dynamics in social interactions and identify problems and resources to improve mental well-being. Theoretically, this benefit may translate into other positive constructs related to mental well-being. The

two studies above have shown the potential of such benefits on positive self-belief, subjective happiness, and mental well-being.

A systematic review on social media-based intervention to improve awareness and mental health self-efficacy has reported an increase in advocacy activity, positive thinking, and help-seeking behaviour among diverse population (Draganidis et al., 2024). This review provided clues on the possible benefits of improving mental health self-efficacy among adult population. The MySEM activity has reported significant improvement in optimism and factor coping which is conceptually related to positive thinking and help-seeking behaviour. These benefits become more pertinent as a recent study among Malaysian adults reported home- or work-related stress significantly predicted depressive symptoms (Mohd Tamil et al., 2024). Home and work-related stresses have a dynamic and consequential impact on each other. This is especially tangible as most of an adult's productive hours were spent at work. The MySEM activity included the exploration of social ecology in both settings and how the interactions within the microsystem and mesosystems contributed to the current state of mental health. Causes of stress may originate primarily from one specific interaction and affect subsequent interactions: producing an incremental cycle of the stress level. Gaining insight into these dynamics within and between home and work settings may have contributed to better factor coping.

The advocacy subdimension measured the degree to which respondents were confident in advocating for their personal needs and did not show significant changes before and after the MySEM activity. This may possibly be due to the lack of exploration of the intrapersonal needs in the MySEM activity. Current exploration focuses mainly on the interactions within the micro- and mesosystems. Advocacy for personal needs may also involve assertive communication skills and awareness. Future research may consider exploring the intrapersonal system for personal needs and identifying skills needed to advocate for it.

Uniquely, the MySEM activity included the appreciation of the current home or work-related interactions within the context of time (chronosystem). Conflicts that arise in either setting may have been contributed to by the temporal effect of the experience. For example, suddenly caring for a sick child at home will affect quality sleep and work performance in subsequent days. Both experiences may show compounding contributions to the stress level and may improve as the sick child recovers. The appreciation of temporal effect may have contributed to the improvement in optimism as participants gained insight into the transient nature of their current experience. Future research may consider improving the exploration process to include solution-focused questions to guide participants in determining their actions. Clarifying needs and purpose will be the first step towards making constructive actions to improve their state of mental well-being.

The MySEM tool offers several practical applications for mental health professionals to enhance both individual and community mental health outcomes. It can be used to assess an individual's readiness to engage in therapeutic interventions. This baseline information can guide treatment planning and allow for the development of tailored interventions that focus on improving areas of low self-efficacy, thereby increasing both engagement and effectiveness. The assessment of readiness provides valuable baseline data, which can then be used in follow-up evaluations to monitor treatment progress and make necessary adjustments. This will ensure that therapeutic strategies are aligned with the evolving needs of the individuals.

Besides that, the tool allows for tailored interventions based on an individual's need for psychoeducation; helping individuals understand how self-efficacy influences their mental health within the specific context of their social ecology. By addressing areas of low self-efficacy, individuals can be empowered to develop the skills and confidence needed to improve their mental well-being. Studies suggested that individual psychoeducation interventions based on integrated self-awareness and self-determination were associated with a significant increase in self-efficacy (Engku Kamarudin et al., 2020). Moreover, in group settings, the tool can highlight common areas where participants may struggle, such as coping or optimism. This information can guide the development of group interventions that target these collective challenges, such as stress management or resilience-building exercises.

The current tool focuses on exploring the intrapersonal, microsystem, and mesosystem of an individual. According to the theory, the exosystem and macrosystem were yet to be developed for exploration. This would enable appreciation of the stakeholder and culture in influencing the interaction between the individual and their microsystem and within the mesosystem. However, much of the influence was outside of the individual's control and less helpful for developing coping strategies and therapeutic plans. Nevertheless, the understanding of exosystem and macrosystem influence on an individual may enable deeper exploration and instigate fundamental change in an individual.

The tool may also benefit from multiple studies replicating

the same methodology as the criterion-related validation study. The current evidence suggested benefits from a small sample of university staff from a single public university. Interaction dynamics may be different in other institutions or populations.

In all, the MySEM tool showed potential and value in assisting mental health professionals in exploring the social ecology of their clients, developing insights into interactions and resources, and improving mental health self-efficacy. Additionally, the mental health self-efficacy tool can be applied in practice by mental health professionals to assess, track, and enhance various aspects of mental health. It offers a framework for understanding individual's needs, personalizing interventions, and fostering empowerment. By using this tool, professionals can better support individuals in building the skills and confidence necessary to manage their mental health more effectively.

Training and certification activities may be organised to introduce and guide mental health professionals in utilising the tool. Currently, the tool was prepared for a trained facilitator to administer the tool during the psychotherapy session. The process of drawing may also be improved by using information technology to assist clients in drawing their social ecology. This would reduce time taken during consultation with mental health professionals. Such improvement will enable equitable access to mental health professionals, especially in commercial service centres.

CONCLUSION

The MySEM tool showed good content and face validity among experts and working adults. The tool has promising benefits in improving mental health self-efficacy through increasing factor-coping and optimism. The MySEM tool provided a standardised approach to apply the Bronfenbrenner's Ecology Systems theory for use by mental health professionals.

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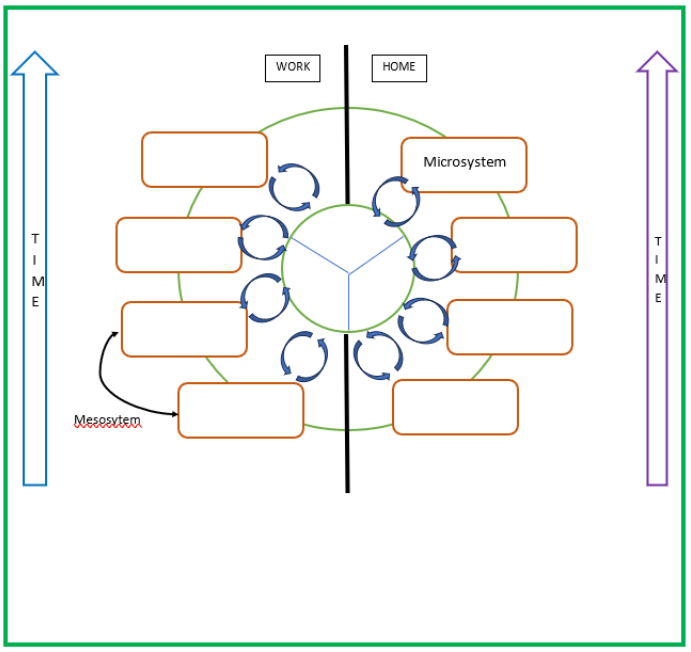

Figure 1: MySEM template for drawing intrapersonal, microsystem, and mesosystem interactions.

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ORIGINAL ARTICLE

Determinants of Hand Hygiene Compliance and Practice Among Nurses from West-coast Malaysia

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ABSTRACT

Background: The Centers for Disease Control and Prevention emphasizes hand hygiene as a key strategy to reduce healthcare infection transmission. However, its significance is often overlooked, and compliance rates are low. This study aimed to assess self-reported hand hygiene compliance and practice among nurses at selected hospitals of West-coast Malaysia. **Methods:** A cross-sectional study using simple random sampling was conducted among 388 nurses from four hospitals, including private and government settings. A questionnaire on sociodemographic data, self-reported hand hygiene compliance and practices scale questionnaire were given to participants. Simple and multiple linear regression was used to identify associated factors with self-reported hand hygiene compliance and practice. **Results:** Analysis showed male nurses with degrees and diplomas outperformed female nurses in hand hygiene compliance and practice scores. Post-hoc analysis using Games-Howell revealed significant differences in self-reported hand hygiene compliance and practice between Malays (25.33, SD=2.57), Chinese (22.16, SD=3.55), and Indians (21.70, SD=1.36, P<0.001)In terms of the mean practice score, significant differences were observed between Malays (41.99, SD=3.74) and Chinese (54.31, SD=6.09) when compared with Indians (44.07, SD=1.89), P<0.001. The results found a significant difference (P<0.001) in nursing practice between Chinese and Indians. However, the mean practice score for the 'Others' group (47.50, SD=6.55) does not show any significant differences from those of Malays (P=0.170), Chinese (P=0.082), and Indians (P=0.498). **Conclusion:** Male nurses with degrees and diplomas outperformed females in self-reported hand hygiene compliance and practice scores, with Indian nurses scored higher on the hand hygiene compliance scale, while Chinese nurses outperformed Indian nurses in terms of nurses' practice scores. A quality improvement project aims to improve hand hygiene compliance and practice among nurses by identifying root causes is needed.

INTRODUCTION

Hand hygiene is a primary factor in reducing healthcare-associated infections (HAIs), which are a leading cause of harm, jeopardizing patient safety and increasing the disease burden (United Nations Children's Fund and World Health Organization, 2021)and account for about 25 infections in every 100 patient admissions in both developed and developing countries and remain the world's top contributor of morbidity and mortality (World Health Organization, 2020).A systematic review reveals high HAIs prevalence in Southeast Asian countries, posing a significant public health risk due to its high transmission rate (Goh et al., 2023). The first line of defence against many HAIs and illnesses linked to healthcare is good hand hygiene. Good hand hygiene helps reduce the microorganisms responsible for HAIs (Gammon and Hunt, 2019; McMichael, 2019). The Centre for Disease Control and Prevention (CDC) (2020) emphasizes the importance of healthcare personnel adhering to hand hygiene rules and recommendations in high-risk environments, exposing patients and health professionals to numerous microorganisms. Hand hygiene, particularly among nurses, is crucial for controlling HAIs. However, poor hand hygiene compliance remains a global challenge for health professionals (Pires et al., 2017). According to the World Health Organization (2022) report, hand hygiene compliance reduces pathogen spread, improves patient safety, and reduces hospital-acquired infections (HAIs), with 7% in developed countries and 10% in developing countries. Hand-hygiene compliance is defined as the proportion of observed handwashing practices using soap and water or alcohol-based hand-rubbing during any of 'the five moments of hand hygiene', as outlined by the

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World Health Organization (Toney-Butler et al., 2022) which is the most efficient and cost-effective intervention in healthcare settings (Engdaw et al., 2019). The World Health Organization recommends using a validated observation tool as a method for assessing hand hygiene adherence (McDonald et al., 2021).

Nurses are crucial in fighting infections and preventing healthcare-associated infections (HAIs)(Verbeek et al., 2020). However, global practices at the point of care remain suboptimal. Observing hand hygiene guidelines is crucial in minimizing infection risk in hospitalized patients (Ashinyo et al., 2021). There is a lack of research on Malaysian nurses' self-reported hand hygiene compliance and practice in preventing HAIs. A local study published 11 years ago focused on intensive care unit nurses' compliance with hand hygiene practice and knowledge at one public hospital (Ho et al., 2013). Still, it did not include nurses' self-reported hand hygiene compliance variables. Another study published three years ago focused on self-reported hand hygiene performance predictors among East Coast Malaysian nurses (Rahim et al., 2021). A more recent study examined hand hygiene knowledge, perception, and self-reported performance among East Coast Malaysian nurses (Abd Rahim and Ibrahim, 2022).

Hand hygiene practice varies based on various factors, including the individuals involved, the healthcare system, work characteristics and culture. Also, among the multidisciplinary healthcare professionals who frequently provide patient's bedside care and have direct patient contact are nurses. Therefore, drawing a realistic view of hand hygiene compliance and the factors that impact nurses' hand hygiene practice in Malaysia is difficult. This study aimed to assess self-reported hand hygiene compliance and practice among nurses at selected hospitals of West-coast Malaysia to fill a gap in the literature. The findings of this multisite, cross-sectional study among nurses will provide important evidence for formulating, developing, and applying infection prevention and control (IPC) strategies to support enduring and reliable IPC procedures. This study's findings will also serve as a foundation for future research and provide practical recommendations for programme planners, implementers, and policymakers to enhance hand hygiene compliance in hospitals.

MATERIALS AND METHODS

Ethical Approval

This study was approved by the National Medical Research Register (NMRR) Ethics Committee Malaysia, with a reference number of (09) dlm. KKM/NIHSEC/P15-488.

Study Design

This study utilized a cross-sectional study.

Subjects and Study Setting

A stratified sampling was used. Four hospitals (General Hospital Kuala Lumpur and Universiti Malaya Medical Centre) and two private hospitals (KPJ Damansara Specialist Hospital, Petaling Jaya and Thomson Medical Center, Petaling Jaya) were the first strata with the next being the types of departments in each hospital. A simple random sampling was performed to select the participants from each department, ensuring that participants had an equal chance of being chosen. The inclusion criteria were nurses with at least six months of involvement in clinical services and who had direct contact with patients. Nurses with IPC training was excluded due to the issue of confounders, as they have acquired sufficient knowledge and training to adhere to IPC guidelines. In this study, sample homogeneity was ensured by establishing eligibility and exclusion criteria, collecting data at the same time, assigning one researcher for data collection, and randomly assigning subjects to groups. A single-proportion method was used to estimate the sample size, based on Asmr et al.'s (2019) study on participants' knowledge of infection prevention and practice in Addis Ababa, Ethiopia, under the assumption of a 5% margin of error and a 95% confidence interval (CI). The computed sample size was 353. With a 10% non-response rate taken into account, 388 was the final projected sample size for this study.

Instrument

The study used a self-administered, structured questionnaire in English, adapted from Van de Mortel (2009) and Mitchell (2014), with permission to assess hand hygiene compliance and IPC practices. The questionnaire included sociodemographic characteristics (age, gender, race, highest nursing education and years of work experience), self-reported hand hygiene compliance, and IPC practices. The questionnaire, consisting of 14 items, used a 5-point Likert scale with a choice of answer as "1=strongly disagree", "2=disagree", "3=neutral", "4=agree", and "5=strongly agree" with higher scores indicating higher levels of hand hygiene compliance and practice. A pilot study prior to the actual

study was performed with 38 nurses to assess the comprehensibility, practicability, and acceptability of the adapted instrument from Van de Mortel (2009) and Mitchell (2014), and results were not included in the study findings. Cronbach's alpha test yielded a 0.7 value, indicating acceptable item reliability (Taber, 2018).

Data Collection

Data collection was conducted from October to December 2019. The lead researcher distributed invitation letters to nursing matrons and ward sisters in each hospital, followed by email invitations and electronic recruitment posters to the nurses.

Data Analysis

All data was analysed using the Statistical Package Software for Social Science (SPSS) version 26.0 for Windows. Continuous variables were reported as mean and standard deviation, while categorical variables were expressed as numbers and percentages. Numerical data analysis, including independent t-tests and one-way ANOVA tests, was used to assess data normality. Parametric tests were applied when the histogram indicated a normal distribution. Post-hoc tests were conducted using the Games-Howell test. Simple and multiple linear regression was used to identify associated factors with self-reported hand hygiene compliance and practice. Statistical significance was set at $P<0.05$.

RESULTS

Nurses' Demographic Characteristics

Table 1 showed the demographic of 388 participants. The mean age was 27.89 (SD 5.49), with 59.3% females and 51.8% Malays. 48.2% were non-Malay (Chinese, Indians and Other races). Over half (63.7%) had a diploma in nursing, while the remainder had a bachelor's degree. Most had at least 2.92 years of work experience.

Table 1: Demographic characteristics of participants, n=388

Characteristics	n (%)	Mean (SD)
Age, mean (SD)		27.89 (5.49)
Gender		
Male	158 (40.7)	
Female	230 (59.3)	
Ethnicity		
Malay	201 (51.8)	
Chinese	146 (37.6)	
Indian	33 (8.5)	
Others	8 (2.1)	
Highest nursing education		
Diploma	247 (63.7)	
Degree	141 (36.3)	
Years of working experience, mean (SD)		2.92 (1.45)

Nurses' Self-Reported Hand Hygiene Compliance

Table 2 presents the nurses' self-reported hand hygiene compliance scale. The study reveals that 45.9% of nurses believe they serve as role models for other health professionals, with 52.3% believing hand hygiene could reduce patient mortality and medical costs associated with HAIs. However, only 66% believe prevention of HAIs is part of their role, and 38.2% believe they can change workplace practices. Nearly half of the nurses (42.2%) agreed that they follow senior nurses' hand hygiene habits and consider failure to perform hand hygiene as negligence. Over half of nurses are confident in applying good habits during clinical practice, with 52% performing hand hygiene in clinical settings without extra effort. Additionally, 50.3% remind other healthcare workers to adopt hand hygiene habits, and 40.7% research hand hygiene to address discrepancies between guidelines and practice.

Nurses' Self-Reported Hand Hygiene Practice

Table 3 displays the nurses' self-reported hand hygiene practice. The study found that 38.9% of participants disagreed or strongly disagreed with the use of alcohol-based solutions before and after patient transfers, but 86.1% would use them before opening vascular access equipment. 61.1% agreed to use alcohol-based solutions before and after nursing care procedures. More than half (59.2%) of nurses would wash their hands before and after blood drawing. Less than half of nurses agreed to perform hand hygiene when a urinary catheter was inserted, cleaning body sites, and touching inanimate surfaces. 42.3% of nurses occasionally wear nail polish or artificial nails, but 48.7% always remove rings or bracelets before performing hand hygiene. The majority of nurses were compliant with recommended guidelines for reducing HAI transmission during emergencies.

Comparison of Results Between Gender, Education Level and Race

Table 4 compares results between gender and education level using the independence t-test. There was a statistically significant difference in the mean hand hygiene score between males [67.25 (SD=6.47)] and females [56.77 (SD=2.57)], $P<0.001$. The mean hand hygiene compliance score of males was higher than that of females. Males had a better practice score than females. Regarding the comparison of results between education level, nurses with a degree [68.33 (SD=5.96)] had better scores in hand-hygiene practice than diploma nurses [56.87 (SD=2.57)] with a point difference of 11.46 ($P<0.001$).

Table 2: Nurses' self-reported hand hygiene compliance (n=388)

No	Statements	Strongly Disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly Agree n (%)
1	I have a duty to act as a role model for other healthcare workers	31 (8.0)	110 (28.4)	69 (17.8)	53 (13.7)	125 (32.2)
2	The importance of completing tasks over performing hand hygiene is often prioritized when busy.^	219 (56.4)	28 (7.2)	111 (28.6)	9 (2.3)	21 (5.4)
3	Performing hand hygiene in the recommended manner can significantly decrease patient mortality	50 (12.9)	72 (18.6)	63 (16.2)	88 (22.7)	115 (29.6)
4	Performing hand hygiene in the recommended situations can reduce medical costs associated with hospital-acquired infections	54 (13.9)	87 (22.4)	43 (11.1)	81 (20.9)	123 (31.7)
5	I can't always perform hand hygiene in recommended situations because my patient's needs come first^	70 (18.0)	98 (25.3)	59 (15.2)	143 (36.9)	18 (4.6)
6	Prevention of hospital-acquired infection is a valuable part of a healthcare professional's role	40 (10.3)	25 (6.4)	67 (17.3)	93 (24.0)	163 (42.0)
7	I follow the example of senior nurses when deciding whether or not to perform hand hygiene^	65 (16.8)	115 (29.6)	44 (11.3)	58 (14.9)	106 (27.3)
8	I believe I have the power to change poor practices in the workplace	95 (24.5)	57 (14.7)	88 (22.7)	34 (8.8)	114 (29.4)
9	I believe failure to perform hand hygiene in the recommended situations can be considered negligence	89 (22.9)	56 (14.4)	80 (20.6)	109 (28.1)	54 (13.9)
10	Hand hygiene is a habit for me in my personal life	0 (0.0)	65 (16.8)	111 (28.6)	109 (28.1)	103 (26.5)
11	I am confident I can effectively apply my	30 (7.7)	58 (14.9)	85 (21.9)	82 (21.1)	133 (34.3)

	knowledge of hand hygiene to my clinical practice					
12	It is an effort to remember to perform hand hygiene in the recommended situations^	101 (26.0)	101 (26.0)	92 (23.7)	40 (10.3)	54 (13.9)
13	I would feel uncomfortable reminding a health worker to handwash^	83 (21.4)	112 (28.9)	71 (18.3)	71 (18.3)	51 (13.1)
14	If I disagree with a guideline, I look for research findings to guide my practice	80 (20.6)	79 (20.4)	71 (18.3)	76 (19.6)	82 (21.1)
Total score, mean (SD)						**61.04 (6.89)**

Scale: 1=strongly disagree to 5= strongly agree; ^ indicates the item is reverse coded

Table 3: Nurses' self-reported hand hygiene practice (n = 388)

No	Statements	Strongly Disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly Agree n (%)
1.	I follow recommended guidelines for the use of alcohol-based solutions or other antiseptics before and after helping a patient to move, lift or transfer the patient in and out of bed.	97 (25.0)	54 (13.9)	77 (19.8)	67 (17.3)	93 (24.0)
2	I follow recommended guidelines for the use of alcohol-based solutions or other antiseptics before opening vascular access equipment.	0 (0.0)	14 (3.6)	40 (10.3)	189 (48.7)	145 (37.4)
3	I use alcohol-based solutions or other antiseptics between each patient contact.	43 (11.1)	30 (7.7)	144 (37.1)	91 (23.5)	80 (20.6)
4	I wash my hands or rub with an alcohol-based solution or other antiseptics before and after providing a nursing procedure, for example, a bed bath or perineal care.	50 (12.9)	35 (9.0)	66 (17.0)	126 (32.5)	111 (28.6)
5	I wash my hands or rub them with an alcohol-based solution or other antiseptics after contact with equipment objects likely to be contaminated, followed by patient care activity, e.g., taking vital signs.	44 (11.3)	46 (11.9)	74 (19.1)	126 (32.5)	98 (25.3)
6	I wash my hands before and after drawing or manipulating the patient's body fluid sample.	15 (3.9)	71 (18.3)	72 (18.6)	96 (24.7)	134 (34.5)

7	I always wash my hands before and after having direct contact with a patient's intact skin.	24 (6.2)	109 (28.1)	131 (33.8)	49 (12.6)	75 (19.3)
8	I always wash my hands before and after inserting indwelling urinary catheters.	90 (23.2)	73 (18.8)	100 (25.8)	0 (0.0)	125 (32.2)
9	I always wash my hands when moving from a contaminated body site to a clean body site during patient care.	79 (20.4)	54 (13.9)	86 (22.2)	78 (20.1)	91 (23.5)
10	I occasionally polish my fingernails or wear artificial nails.	64 (16.5)	76 (19.6)	84 (21.6)	121 (31.2)	43 (11.1)
11	I am less compliant with recommended guidelines for reducing transmission of nosocomial infections when workload increases or in emergencies.	50 (12.9)	110 (28.4)	94 (24.2)	66 (17.0)	68 (17.5)
12	I wash my hands after touching inanimate surfaces and objects in the patient's surroundings	63 (16.2)	60 (15.5)	76 (19.6)	86 (22.2)	103 (26.5)
13	I chart or use the computer keyboard with my gloves on during a busy patient care episode.	63 (16.2)	13 (3.4)	105 (27.1)	118 (30.4)	89 (22.9)
14	I remove my ring{s}, watch or bracelet before beginning hand hygiene	14 (3.6)	38 (9.8)	147 (37.9)	19 (4.9)	170 (43.8)
Total score, mean (SD)						**46.91 (7.49)**

Table 4: Comparison of scales between gender and educational level (n=388)

Characteristics	**Mean (SD)**		**Mean difference (95% CI)**	**t-statistic (df)** [a]	**P value**
	Male (n=158)	**Female (n=230)**			
Nurses' self-reported hand hygiene compliance score	67.25 (6.47)	56.77 (2.57)	10.48 (11.55, 9.41)	19.33 (191.34)	< 0.001*
Nurses' self-reported hand hygiene practice	50.49 (8.02)	44.46 (5.98)	6.04 (7.51, 4.56)	8.05 (272.64)	< 0.001*
	Diploma (n= 247)	**Degree (n= 141)**			
Nurses' self-reported hand hygiene compliance score	56.87 (2.57)	68.33 (5.96)	11.46 (12.50, 10.42)	21.70 (170.22)	< 0.001*
Nurses' self-reported hand hygiene practice	44.24 (5.79)	51.60 (7.83)	7.36 (8.73, 5.99)	9.75 (228.52)	< 0.001*

Key: [a] Independent t-test; * Statistically significant

Table 5 shows the comparison of scales between races. The scales (nurses' self-reported hand hygiene compliance and practice score) exhibit significant differences between races using a one-way ANOVA test, P<0.001. The post-hoc analysis using Games-Howell on nurses' self-reported hand hygiene compliance and practice. Regarding the mean self-reported hand-hygiene compliance scores, Malays (25.33, SD=2.57) and Chinese (22.16, SD=3.55) are significantly different compared with Indians (21.70, SD=1.36), P<0.001. However, there are no significant differences between Malays (P=0.945), Chinese (P=0.157), and Indians (P=0.085) in the 'Others' group (24.75, SD=3.00). Significant differences in mean practice scores were observed between Malays (41.99, SD=3.74), Chinese (54.31, SD=6.09), and Indians (44.07, SD=1.89, P<0.001).The results found a significant difference (P<0.001) in nursing practice between Chinese and Indians. However, the mean practice score for the 'Others' group (47.50, SD=6.55) does not show any significant differences from those of Malays (P=0.170), Chinese (P=0.082), and Indians (P=0.498). In conclusion, Indian nurses scored higher on the hand hygiene compliance scale, while Chinese nurses outperformed Indian nurses in terms of nurses' practice scores.

Table 5: Comparison of scales between races (n=388)

Variables	Mean (SD)				F-statistics (df) [a]	P value
	Malay (n= 201)	Chinese (n= 146)	Indian (n= 33)	Others (n= 8)		
Nurses' self-reported hand hygiene compliance score	25.33 (2.57)	22.16 (3.55)	21.70 (1.36)	24.75 (3.00)	39.84 (3,384)	< 0.001*
Nurses' hand hygiene practice	41.99 (3.74)	54.31 (6.09)	44.07 (1.89)	47.50 (6.55)	195.72 (3, 384)	< 0.001*

Key: [a] One-way ANOVA test; * Statistically significant

Post-hoc analysis using Games-Howell:

Self-Reported Hand Hygiene Compliance	Nurses' Hand Hygiene Practice
Malay vs Chinese and Indian, p < 0.001*	Malay vs Chinese and Indian, p < 0.001*
Malay vs Others, p=0.945	Malay vs Others, p=0.170
Chinese vs Indian, p< 0.001*	Chinese vs Indian, p< 0.001*
Chinese vs Others, p=0.157	Chinese vs Others, p=0.082
Indian vs Others, p=0.085	Indian vs Others, p=0.498

* Statistically significant

Associated Factors of Self-Reported Hand Hygiene Compliance Among Nurses

Table 6 presents the associated factors of self-reported hand hygiene compliance among nurses using simple and multiple linear regression. Age, gender, race, education level, and years of work experience were significant predictors of self-reported hand hygiene compliance (P<0.001). In the simple linear regression analysis, a 1-year increase in age was associated with a 0.23 unit decrease in the score. Males had a 7.97 times higher chance of having a high hand hygiene belief score than females. Indian nurses had the highest score in self-reported hand hygiene compliance (11.41), followed by Chinese and other races, compared with Malays. Nurses with a degree had an 8.63 times higher chance of having high hand hygiene compliance than diploma holders. Those with one additional year of work experience had a 2.70 times higher chance of having a high hand hygiene belief score. In the multivariate analysis, gender, race, education level, and years of work experience remained significant predictors of the hand hygiene belief scale (P<0.001). Indian male nurses with a degree tend to have a higher self-reported hand hygiene compliance score than other nurses when considering other confounding factors. However, those with longer work experience have a 0.48 lower self-reported hand hygiene compliance score.

Table 6: Associated factors of self-reported hand hygiene compliance among nurses (n=388)

Variables	Simple linear regression b[a] (95% CI)	P-value	Multiple linear regression b[b] (95% CI)	P-value
Age	0.23 (0.14, 0.32)	< 0.001*	-	-
Gender				
Female	0	1	0	1
Male	7.97 (7.35, 8.60)	< 0.001*	2.56 (1.66, 3.45)	< 0.001*
Races				
Malay	0	1	0	1
Chinese	6.87 (6.25, 7.50)	< 0.001*	2.20 (1.32, 3.09)	< 0.001*
Indian	11.41 (10.32, 12.49)	< 0.001*	4.58 (3.20, 5.96)	< 0.001*
Others	6.77 (4.69, 8.85)	< 0.001*	3.43 (1.68, 5.19)	< 0.001*
Education				
Diploma	0	1	0	1
Degree	8.63 (8.06, 9.20)	< 0.001*	2.95 (1.79, 4.11)	< 0.001*
Years of Working Experience	2.70 (2.49, 2.91)	< 0.001*	0.48 (0.14, 0.82)	0.006*

Key: [a] Crude regression coefficient; [b] adjusted regression coefficient; *Statistically significant
Stepwise, backward and forward multiple linear regression methods were applied.

Associated Factors of Nurses' Hand Hygiene Practice Scores

Table 7 presents the associated factors of nurses' practice scores among study participants using simple and multiple linear regression. Age, gender, race, education level, and years of work experience influenced nurses' practice scores in simple linear regression. An increase of 1 year in age corresponded to a 0.27-point decrease in practice scores. Males scored 6.04 points higher than females on the practice scale. Chinese nurses achieved the highest practice scores compared to Malays, followed by other races (5.51 points) and Indians (2.07 points). Degree-holding nurses scored 7.36 points higher in practical skills than diploma-holders. Experienced nurses had a practice score of 2.46 points higher than junior nurses. The study's multiple linear regression analysis revealed that practice scores were significantly influenced by age and race. A 1-year increase in age resulted in a 0.28-point decrease in practice scores when adjusted for race. When age was taken into account, Chinese nurses had a 12.36-point greater probability of scoring on the practice scale than other racial groups, including Malays.

DISCUSSION

Hand hygiene compliance and practice are critical in preventing HAIs, as they disrupt the transmission cycle and mitigate risk. This present cross-sectional study assessed nurses' self-reported hand hygiene compliance and practice at four hospitals in Malaysia. This study reveals that nurses' mean age was 27.89 (5.49). Male nurses with degrees and diplomas outperformed females in self-reported hand hygiene compliance and practice scores. Chinese nurses had a 12.36 times higher chance of scoring on the hand hygiene practice scale. The average scores for the diploma and degree nurses were both higher than the average scores for the group of female nurses. Gender, race, education level, and years of working experience were significant predictors of self-reported hand hygiene compliance. Considering the age of nurses, the results are similar to results for the young nursing workforce in studies conducted in southern Malawi (Nzanga et al., 2022) and eastern Ethiopia (Umar et al., 2022).

The present study reveals that females dominate the nursing profession globally, with a significant gender gap. Female-dominated nursing is well-recognized globally, highlighting the vast gap ratio between females and males (Adhanom, 2019). However, in this study, male nurses, particularly degree and diploma nurses, have higher hand hygiene compliance and practice scores, aligning with Kamunge's (2013) study that found males perform hand hygiene compliance more than females. Contrary, Mohaithef 's (2020) study found that good hand hygiene practice was higher among female nurses

Table 7: Associated factors of hand hygiene practice score among nurses (n=388)

Variables	Simple linear regression b[a] (95% CI)	P-value	Multiple linear regression b[b] (95% CI)	P-value
Age	- 0.27 (-0.41, -0.14)	< 0.001*	- 0.28 (-0.37, -0.18)	< 0.001*
Gender				
Female	0	1		
Male	6.04 (4.64, 7.44)	< 0.001*	-	-
Races				
Malay	0	1	0	1
Chinese	12.32 (11.31, 13.33)	< 0.001*	12.36 (11.39, 13.33)	< 0.001*
Indian	2.07 (0.32, 3.82)	0.020*	4.33 (2.50, 6.17)	< 0.001*
Others	5.51 (2.16, 8.86)	0.001*	6.98 (3.74, 10.23)	< 0.001*
Education				
Diploma	0	1		
Degree	7.36 (5.99, 8.74)	< 0.001*	-	-
Years of Working Experience	2.46 (2.01, 2.91)	< 0.001*	-	-

Key: [a] Crude regression coefficient; [b] adjusted regression coefficient; * Statistically significant
Stepwise, backward and forward multiple linear regression method were applied.

than among male nurses. This difference may be due to females being more aware of their safety and others' safety and cultural influences, whereas males are more socially dominant. Further exploration is needed to understand the relationship between gender, hand hygiene compliance, and practice among nurses.

Findings from this study reveal that Indian male nurses with degrees have higher average scores in self-reported hand hygiene compliance. In comparison, Chinese nurses have higher scores in self-reported hand hygiene practice. Pittet et al. (2009) found that cultural and religious influences significantly influence attitudes towards communal handwashing, as per the WHO Guidelines on Hand Hygiene in Health Care. In Hindu culture (Indians), hand cleansing is a measure of preventing the spread of disease. The practice is clearly in harmony with the Hindu values of non-injury to others (ahimsa) and care for their wellbeing (daya).

The present study shows that nurses with higher degrees had higher self-reported hand hygiene compliance and practice scores, indicating a significant association between these factors. According to Abdo et al. (2020) and Bimerew and Muhawenima (2022), education improves knowledge, which in turn impacts individuals' hand hygiene compliance and practice. Hence, indicate education is deemed to be a vital factor in promoting good hygiene practices. Unfortunately, few studies have been done on self-reported hand hygiene compliance and practice among nurses from a multicultural study population linking to education and hand hygiene compliance and practice. Therefore, no similar data was available from other studies allowing the comparison of results according to race. Hence, further exploration to understand the relationship between race, education, self-reported hand hygiene compliance and practice among nurses is needed.

The present study found that work experience was associated with nurses' self-reported hand hygiene compliance and practice. Our findings concur with an earlier study by Omuga (2011) at Kenyatta National Hospital in Kenya, which found that most demographic factors (such as years of work experience) were related to nurses' hand hygiene compliance and practices. Dixit et al.'s (2012) study suggests that years of work experience are crucial for hand hygiene compliance and practice, while Zakeri et al. (2017) and Al Ra'awji et al. (2018) found that more experience lowers hand hygiene knowledge levels among healthcare workers. A possible explanation for this is that when nurses' work experience increases, complacency develops. Thus, hand hygiene knowledge may be less promoted, potentially impacting compliance and practice among experienced nurses. According to Ahmadipour et al. (2022), barriers to hand hygiene practices include individual, manager, and organizational factors. The findings from this study could help bridge the gap between nurses' self-reported hand hygiene compliance and actual practices with work experience.

There are some limitations in this study. The authors

collected data from one state in Malaysia. Therefore, the findings cannot be extrapolated to nurses working in other states who may have had different responses to the present study population. The study's use of a self-administered questionnaire raises the possibility that, even when participants apply identical actions, there may be discrepancies in their responses to some questions about hand hygiene compliance and practice, giving rise to the impression of subject biases. It may be that males tend to be more confident in their abilities compared to females so this would also result in bias. To further distinguish the potential knowledge participants may hold about hand hygiene compliance and practice, including a multiple-choice question that includes an incorrect response regarding hand hygiene knowledge in future studies would be interesting. In this way, researchers may discover if participants choose the incorrect answer randomly or knowingly. In addition, a comparison of the results of this study with those from other contexts, either national or international, is impossible due to a lack of comparable data.

CONCLUSION

In conclusion, male nurses with degrees or diplomas outperformed females in self-reported hand hygiene compliance and practice scores. Indian nurses scored higher on the hand hygiene compliance scale, while Chinese nurses excelled in practice scores. A quality improvement project to identify the root causes of nurses' hand hygiene compliance issues and identify areas for improvement is needed.

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CONFLICT OF INTEREST

The authors have no disclosure of interest, and there are no conflicts to declare.

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REVIEW ARTICLE

Scientometric Analysis of Electrical Modalities in Knee Rehabilitation (1983-2023)

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ABSTRACT

Background: Rehabilitation settings employ electrical modalities as a therapeutic modality to augment or facilitate the recovery of individuals suffering from diverse neurological or musculoskeletal diseases. This intervention requires the application of electrical currents to targeted regions of the body, typically administered via electrodes positioned on the skin, with the intent of eliciting physiological responses and fostering therapeutic benefits. An examination of its trajectory through various analytical lenses, such as bibliometrics, underscores the imperative of comprehending its global ramifications. In recent years, scientometric investigations have emerged as interactive methodologies for evaluating the performance of specific domains of inquiry. These enquiries yield interactive visualisations and figures, affording insights into multifaceted aspects of information. Moreover, scientometric research equips scholars with tools to synthesise evidence gleaned from literature amassed in scientific repositories. **Methods:** The inception of the Web of Science (WOS) database in 1983 has facilitated the aggregation of scientific publications, revealing a discernible uptrend in research pertaining to electrical modalities for knee rehabilitation from 1983 to 2023. This study endeavours to delineate the contemporary landscape of research surrounding electrical modalities for knee rehabilitation through scientometric analysis. **Results:** The progression of scientific publications in this domain demonstrates a consistent upward trajectory. While the volume of publications was inadequate in 1983, comprising merely one paper, this figure surged dramatically, reaching 80 publications by 2019. Furthermore, these publications collectively garnered a substantial citation count of 19,660, precipitating the identification of 27 co-citation clusters through cluster analysis. **Conclusion**: The realm of electrical modalities for knee rehabilitation emerges as a promising frontier for scholarly inquiry. The escalating trajectory of research publications, coupled with the considerable citation impact, underscores the significance and prospective advancements within this sphere.

INTRODUCTION

The knee, a crucial joint in the human body, plays a pivotal role in maintaining mobility and supporting various physical activities. However, knee injuries and conditions often pose significant challenges to individuals, affecting their quality of life (Kawano, Araújo, Castro, & Matos, 2015; McGuine, Winterstein, Carr, & Hetzel, 2014).

Traditional knee rehabilitation methods, though essential, are not without limitations. The journey to recovery can be characterised by prolonged rehabilitation periods and potential difficulties in achieving comprehensive neuromuscular activation (Taradaj et al., 2013). As a result, there is a growing need to explore alternative techniques to enhance knee rehabilitation's efficacy.

Traditional knee rehabilitation methods, though essential, are not without limitations. The journey to recovery can be characterized by prolonged rehabilitation periods and potential difficulties in achieving comprehensive neuromuscular activation (Taradaj et al., 2013). As a result, there is a growing need to explore alternative techniques that can enhance the efficacy of knee rehabilitation.

At the forefront of innovative rehabilitation strategies are electrical modalities, encompassing various techniques

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such as neuromuscular electrical stimulation (NMES), functional electrical stimulation and transcutaneous electrical nerve stimulation (TENS). These modalities leverage controlled electrical impulses to target specific muscle groups, enhance muscle mass and strength, and potentially accelerate the recovery trajectory (Taradaj et al., 2013; Wellauer, Item, Bizzini, & Maffiuletti, 2022).

Scientometric analysis offers a systematic and quantitative approach to examine the scholarly literature on electrical, rehabilitation, knee injury and related areas. By utilizing scientometric techniques, researchers can uncover valuable insights into the trends, patterns, and impact of studies conducted in this domain. This methodology involves the quantitative analysis of publication output, citations, co-authorship networks, keyword frequencies, and other information to reveal the structure and dynamics of the research landscape.

The present study aims to undertake an extensive scientometric investigation centred on the confluence of rehabilitation technology and knee injury research. The search strategy employed encompasses a range of keywords pertinent to electrical modalities, such as "electric" while also incorporating terms related to knee injury, including "knee" and "knee injury," to ensure the retrieval of relevant publications.

This study endeavours to delineate the primary domains and contemporary dynamics surrounding electrical modalities and knee rehabilitation while proposing avenues for future investigation. Employing a scientometric approach, we scrutinize publication trends and the intellectual framework within this domain. Through this rigorous analysis, our aim is to furnish a comprehensive overview of the extant literature, pinpoint influential works, and delineate the principal contributors and research networks in this field. By charting the scientometric terrain, we endeavour to glean insights into the most vibrant research arenas and the trajectory of research trends over time.

To this end, we have delineated four research inquiries. Firstly, recognizing a paucity of reviews concerning sustainability in electrical modalities for knee rehabilitation, we endeavour to address this gap by conducting an exhaustive review of pertinent literature to elucidate prevalent research themes in this domain. Specifically, our research questions (RQs) are structured as follows: RQ1: What are the prevailing trends in publication output concerning board diversity? RQ2: Which articles wield significant influence as conduits of knowledge on board diversity? RQ3: What are the predominant topics or clusters pertaining to board diversity? And RQ4: What are the seminal publications and keywords in the domain of board diversity?

MATERIALS AND METHODS

The research framework for this study, adapted from Azra, Mohd Noor, Sung, Dawood, & Ghaffar, (2022) is presented in Figure 1.

Data Source

The process of accessing online literature was performed by a researcher through the Core Collection database within Thomson Reuters ISI Web of Science (WOS). Queries within WOS were executed utilizing the "topic" (TS) field, encompassing article titles, abstracts, keywords, and automatically generated "KeyWords Plus" terms extracted from the titles of referenced articles. Recent reports underscore WOS as a prominent scientific database, comprising almost 34,000 journals and featuring over 1.8 billion cited references. Recognized for indexing peer-reviewed publications in high-quality journals, WOS spans various disciplines, as emphasized in reports by Aryadoust & Ang, (2021).

Article search and eligibility criteria

Initially, the search concentrated on databases released by the WOSCC from 1975 to early 2024, employing the following search string:

TS= (((train*) OR (rehab*)) AND (electric*) AND (knee))

In adherence to predetermined parameters and the defined scope of this study, the literature reviewed was confined solely to research articles. Materials beyond research articles, such as conference papers, book chapters, review articles, abstracts, letters, data papers, and correction papers, were deliberately excluded. Furthermore, to maintain consistency with the study's outlined scope, timeline, and the constraints of project funding, only articles published in English were considered for inclusion.

Data Analysis

The analysis of the descriptive dataset was conducted using Microsoft Excel, whereas the scientometric analysis of the scientific publication network was performed utilizing CiteSpace version 6.2.R7 (refer to Table 1).

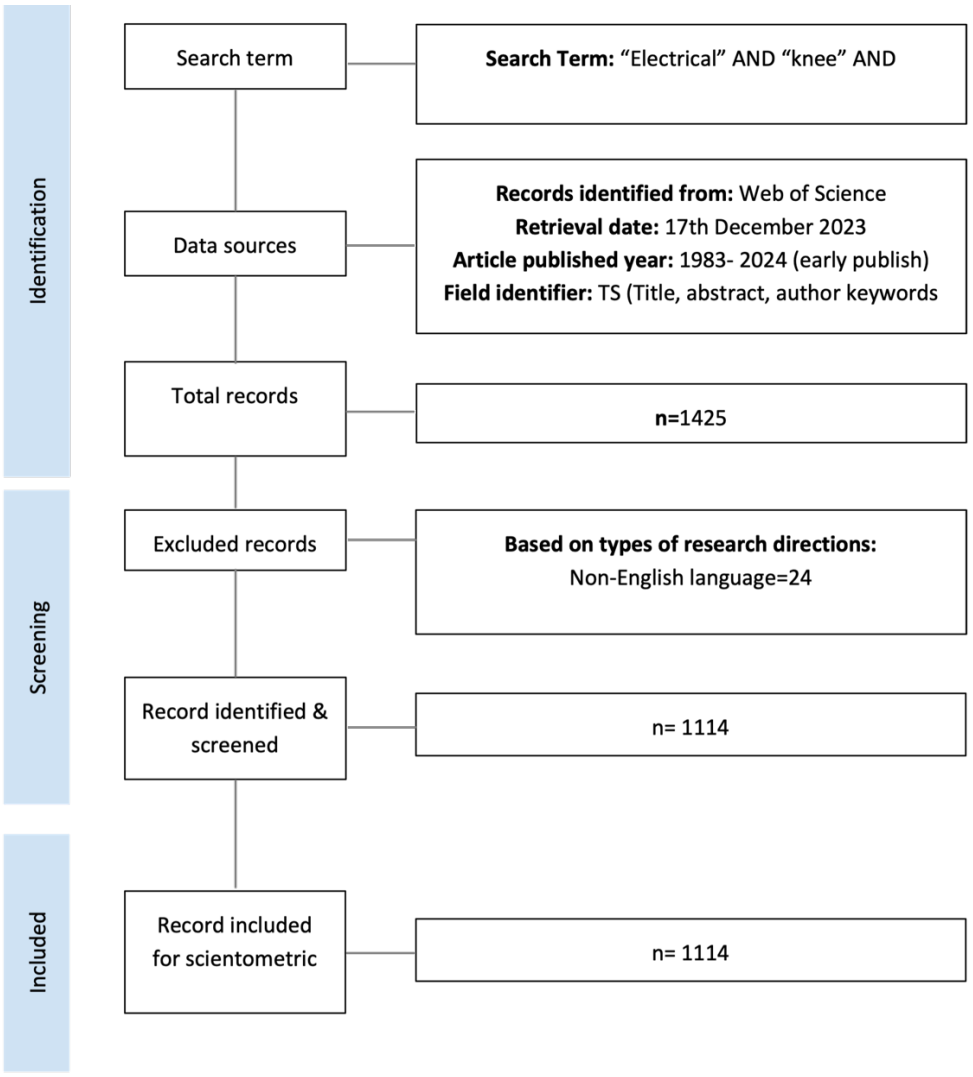

Figure 1: Methodological framework for the current study

All the researchers were together while conducting the analysis in this study to eliminate researcher's errors. This methodology, as elucidated by Azra, Mohd Noor, Sung, Dawood, & Ghaffar, (2022), is extensively employed for discerning trends and patterns within selected research areas or themes.

Scientometric Analysis

In this investigation, CiteSpace version 6.2.R7 served as the primary tool for both visualization and knowledge graph analysis. Renowned for its versatility, this software facilitates the construction of bibliometric networks and the application of diverse analytical techniques (Chen and Leydesdorff, 2014). The threshold setting remained consistent, set to "Top 50 N" per slice, enabling the creation of networks based on the most frequently cited items within each slice. Consequently, the top 50 most cited items identified by CiteSpace were presented and ranked accordingly. The "Time Slicing" parameter was configured to encompass the temporal span from 1983 to 2023, with each slice representing a single year. Additionally, the "Pruning" parameter was employed to refine the generated network. In terms of text processing, all available term sources from Web of Science, including titles, abstracts, author keywords, and keywords plus, were comprehensively integrated into the analysis.

Co-citation Analysis

Co-citation analysis is a crucial tool for evaluating the state of scientific development and the evolving structure of scientific knowledge. This method constructs a science map with nodes, connections, and density values, visually presenting the primary structure of selected variables, particularly Authors in this study (Azizan, 2023). The objective is to identify clusters of co-citing variables, where a co-citation instance occurs when two sources are cited together in a single paper (Chen and Leydesdorff 2014; Aryadoust and Ang 2021).

In evaluating the robustness of variables, researchers have

employed metrics including degree, centrality, and sigma, as documented by prior studies (Chen et al., 2009; Chen & Song, 2019). Degree reflects the frequency of citations a variable garners from other variables of the same category, such as the number of citations one author receives from another author, with a greater degree denoting higher citation frequency. Centrality, on the other hand, gauges the influence of variables by elucidating their proximity within the network. Variables exhibiting high centrality wield significant influence within the network, serving as pivotal points connecting numerous other variables and facilitating the flow of information. Sigma, a composite metric encompassing centrality and burstiness scores, spans a scale from 0 to 1, with elevated values typically associated with high-impact research articles, including those housing raw data and scientifically analyzed findings (Chen et al., 2009; Chen & Song, 2019).

Document Cluster Analysis

Utilizing the gathered documents, a multidimensional clustering approach was implemented to discern research clusters within specified focus domains. The log-likelihood ratio (LLR) method was selected due to its capacity to yield optimal outcomes in terms of both uniqueness and coverage. LLR was utilized to automatically extract cluster labels. The visualization tools "timeline view" and "cluster view" offered by Document Cluster Analysis were employed to depict the structure and configuration of the network. In the "timeline view," chronological time periods were presented along a vertical range from left to right, while the "cluster view" provided a spatial representation of the network landscape, with clusters color-coded and automatically labeled (Aryadoust & Ang, 2021). To evaluate the quality and coherence of the document cluster analyses and the identified clusters, several metrics were employed, including the modularity Q index, average silhouette metric, and centrality metric (Chen et al., 2009; Chen & Song, 2019).The modularity Q index, ranging from 0 to 1, indicated higher reliability with a larger index value. The average silhouette metric, ranging from -1 to 1, denoted greater homogeneity with values surpassing 0. Centrality, serving as a gauge of influence, delineated the extent to which publications or journals interconnected. High centrality publications exerted substantial influence within the network, acting as pivotal connectors for other publications or journals and facilitating the flow of information and pathways through them.

Burstness Analysis

Temporal metrics, namely citation burstiness and sigma, were utilized to pinpoint influential publications and prominent keywords. Citation burstiness denotes the sudden surge in citation count for a particular article, characterized by a sharp spike in citation frequencies within a defined timeframe. This phenomenon is visually depicted by a red ring encircling the respective node(Chen et al., 2009; Chen & Song, 2019).Conversely, sigma represents the aggregate of centrality and burstiness scores, spanning from 0 to 1. A higher sigma value correlates with research articles of significant value (Chen et al., 2009; Chen & Song, 2019).

RESULT

Descriptive Statistics

Evolution of Publications

The study focused on scientific papers released from January 1983 to December 2023, as illustrated in Figure 2. A total of 1114 articles were gathered within this timeframe. Post-2017, there was a gradual upsurge in publications, with 419 articles being published between 2018 and 2023.

Productive Authors

More than 10 publications on electrical modalities for knee rehabilitation have been published by each for top 10 authors since 1983. (Figure 3). Binder-macleod SA had the most publications (22), followed by Triolo RJ (19), and Gorgey AS (18 publications).

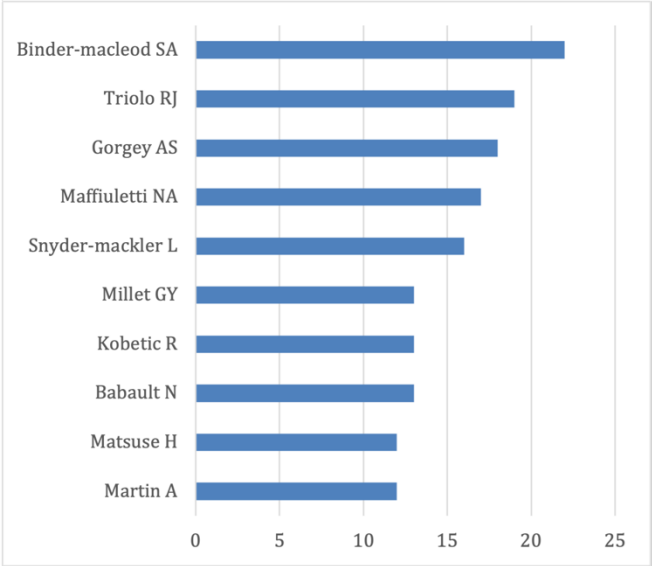

Figure 3: Top ten most productive authors for the period 1983 to 2023

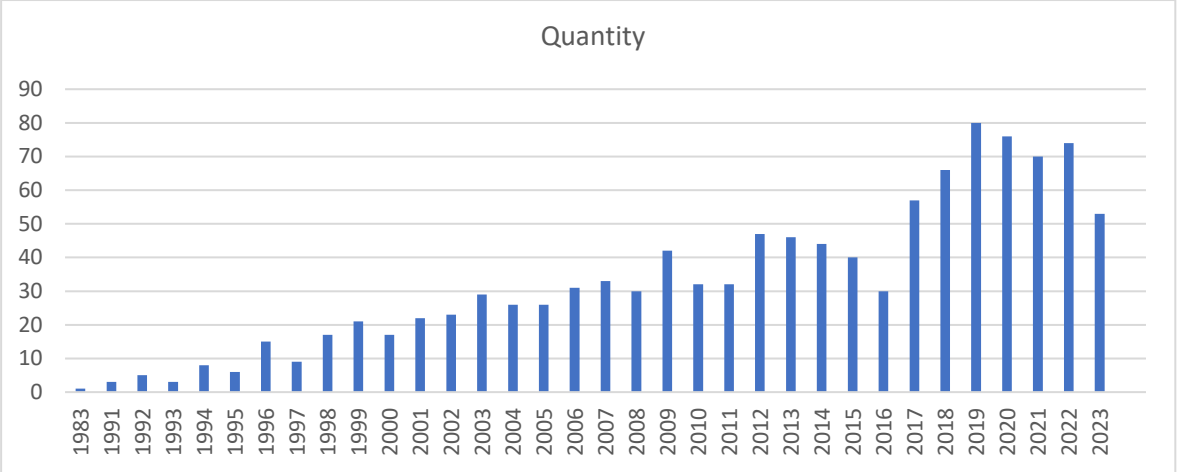

Figure 2: Number of research articles published annually since 1983

Top Institutions

Figure 4 displays the top ten institutions based on their total publications. Leading the list is the University of Delaware in the United States of America, boasting 53 publications, trailed by the United States Department of Veterans Affairs with 44 publications, and the Universite De Bourgogne in France with 40 publications. On average, these top ten institutions published 32 articles each.

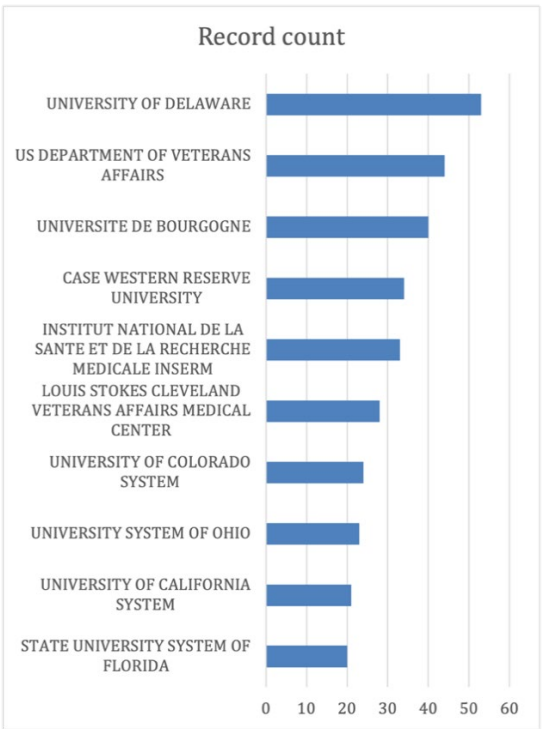

Figure 4: Number of publications from the top ten of 1483 institutions

Productive Journals

Figure 5 illustrates the top ten journals ranked by the number of publications. Across the total pool of eligible articles, we identified content from 1114 journals. Archives of Physical Medicine and Rehabilitation emerged as the top publisher with 63 publications, closely followed by European Journal of Applied Physiology and Medicine and Science in Sports and Exercise, both with 34 publications each. On average, these top ten journals published 27 articles each between 1983 and 2023.

Regional Distribution

Figure 6 displays the top ten countries and regions ranked by the number of publications. Out of the 65 countries with relevant publications, the top ten collectively contributed 86.27% of the total. The United States of America led with 413 publications, followed by France with 94, and Canada with 70 publications.

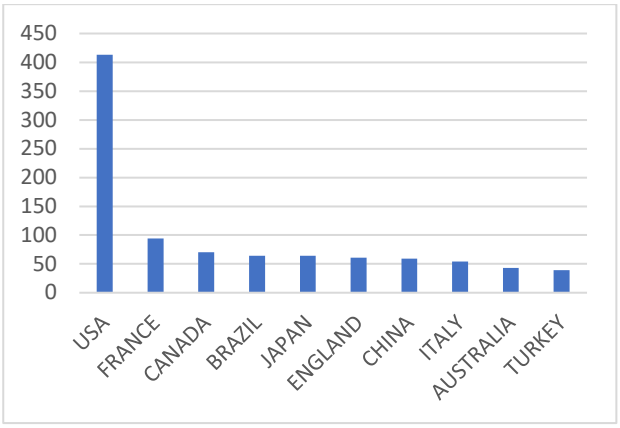

Figure 6: Number of publications published between 1983 and 2023 from the top ten country/region

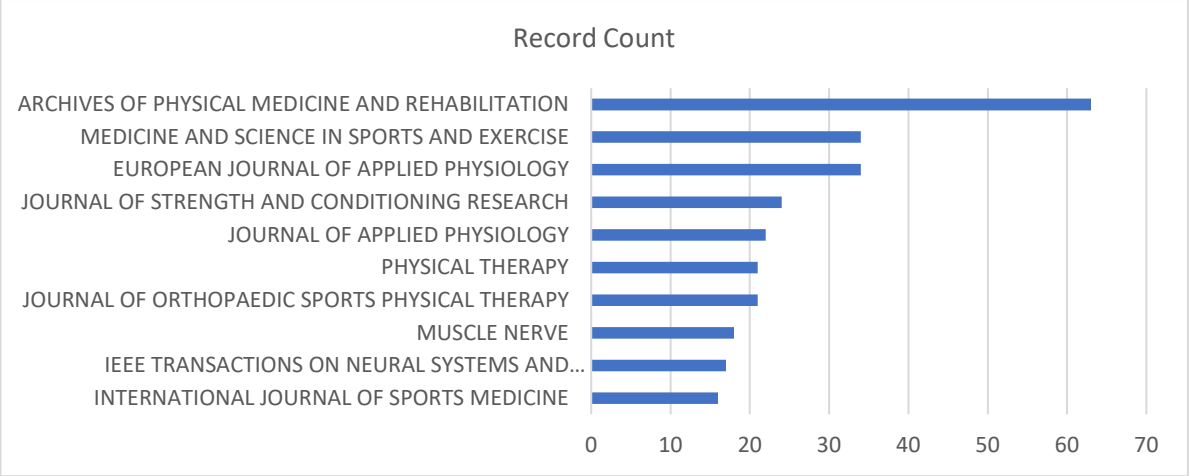

Figure 5: Number of publications published between 1983 and 2023 from the top ten journals

Article-citation based analysis

The top ten articles publications are shown in Table 2. 1114 articles were found to be relevant in this area and the total citations was 19,660. The article by Snydermackler et al (1995) had the most citations (304), followed by Stevens et al (2003) (275 citations), and Seyedin et al (2015) (245 citations).

Scientometric Analysis

Author Co-citation Analysis

Co-citation analysis generates a science map illustrating the main structure of a variable's development status and changes over time, featuring nodes, connections, and density values. The co-citation analysis results for author, journal, country/region, institution, research areas, and article document are presented below. Three parameters, namely (i) degree, (ii) centrality, and (iii) sigma, are employed to identify the most influential author.

The degree parameter represents the number of citations an author receives from another author for the same articles, with a higher degree indicating more citations. Centrality parameters measure the number of times an author is positioned "between" two or more authors, and the author with the highest "betweenness centrality" has the greatest influence on the behavior of the domain areas. The sigma parameter combines the degree and centrality parameters, and a sigma value greater than 1 indicates that the author is in the domain's center (Azra et al., 2022).

Fitzgerald GK emerges as the most connected author with a centrality score of 0.08, a degree of connection of 42, and a sigma of 2.28. Following closely is Duchateau J with a sigma score of 1.19, a centrality score of 0.07, and a degree score of 65. Marsolais EB ranks as the third most influential author with a degree of 27, centrality of 0.07, and a sigma of 1.81. Table 3 lists the top ten authors with the most influence in these fields.

Document Cluster Analysis

The Document Cluster Analysis' Modularity Q Index and Mean Silhouette metrics were 0.8383 and 0.9373, respectively, indicating above-average network reliability and homogeneity. The analysis identified a total of 27 co-citation clusters, and eight of these clusters are summarized on a horizontal line in Figure 7. These clusters were numbered and ranked by size, with the largest cluster labeled as #0. The cluster labels were generated using text mining and a keyword analysis algorithm in CiteSpace software, and the log likelihood ratio (LLR) was utilized for cluster naming.

Table 4 furnishes an overview of the findings stemming from Document Cluster analysis, revealing eight prominent clusters delineating distinct research topics. The magnitude of each cluster is predicated upon the volume of publications encapsulated within. Notably, seven clusters encompass an excess of 50 publications apiece, with Cluster #0 notably concentrating on muscle strength, encompassing a total of 126 publications. The silhouette scores attributed to each cluster spanned a range from 0.889 to 0.962, indicative of a notable degree of homogeneity among publications contained therein (silhouette scores typically range from −1 to 1, with scores surpassing 0 indicative of homogeneity).

Burst Analysis

To identify the most influential or landmark publications as well as keywords, we used a burst analysis. Trends among studies and keywords are described below.

Document Burst

Table 5 presents the top ten publications with the most significant citation bursts, along with the duration of each burst indicated in the rightmost columns. A burst refers to the emergence of a keyword in a publication during a specific time period. The temporal scope extends from 1983 to 2023, delineated by the blue line, with the period of notable surges accentuated by the red line. Particularly noteworthy among these surges is the article entitled "Physiological and methodological considerations for the use of neuromuscular electrical stimulation," characterized by its recent publication and robust burst dynamics, boasting a strength value of 11.85 and a duration spanning from 2017 to 2023. Originally published in the European Journal of Applied Physiology in 2010, this study distinguishes itself within the realm of citation bursts, marking a significant contribution to the scholarly discourse.

Keyword Burst

The keywords with the highest citation burst are listed in Table 6. Over time, keyword analysis has been used to spot emerging trends and research hotspots. The burst represents the appearance of a keyword in the publication of a subject area during a specific time period. The timeline (from 1983 to 2023) is represented by the blue line, while the burst period is represented by the red line. The keywords with the highest frequency in are listed in Table 12. The most frequently used keyword is "people," which appears in the title, abstract, and keyword. The second most common keyword is “movement,” and the third most common keyword is “Spinal cord injury,”.

DISCUSSION

The objective of this research was to conduct a scientometric examination of the effects of electrical modalities in knee rehabilitation, considering it as a prospective avenue for future research endeavors. This chapter delineates the findings and research inquiries, structured around three principal subjects as outlined below:

Evolution of the publication trends in terms of overall publication output

There were a total of 1114 published articles in the area of electrical modalities for knee rehabilitation, when the data was searched back on December 2023. The trend of total published in WOS dramatically increase in 2016 with 30 articles to 57 articles in 2017. Then it continuously increases more than 70 articles in 2018-2022. However, in 2023 the total article reduced to 53.

The most productive author in this area was Stuart Binder-Macleod with 22 publications in WOS. He is employed with the University of Delaware's Department of Physical Therapy. This explains why the University of Delaware, with 53 papers, ranks first among productive institutions for creating articles on electrical modalities for knee rehabilitation. The second productive author is Ronald J. Triolo with 19 publications, working at the Department of Biomedical Engineering, Case Western Reserve University, USA and US Department of Veterans Affairs. The third rank in this area is Professor Ashraf S. Gorgey with 18 publications. He is Director of Spinal Cord Injury Research at Hunter Holmes McGuire at VA Medical Center and Professor at the Department of Physical Medicine and Rehabilitation, Virginia Commonwealth University. Meanwhile, the top three (3) articles with the highest citation counts received were Snydermackler et al (1995), followed by Stevens et al (2003), and Seyedin et al (2015).

The highest article by Snyder-Mackler, Delitto, Bailey, & Stralka, (1995) involved 110 patients undergoing anterior cruciate ligament (ACL) reconstruction, were investigate different treatments between high-intensity neuromuscular electrical stimulation, high-level volitional exercise, low-intensity neuromuscular electrical stimulation and a combination of high and low-intensity neuromuscular electrical stimulation. The results indicated that groups treated with high-intensity electrical stimulation (either alone or combined with low-intensity stimulation) achieved quadriceps strength averaging 70% or more of the strength on the uninvolved side. In contrast, the high-level volitional exercise group reached 57%, and the low-intensity electrical stimulation group reached 51%. Furthermore, knee joint kinematics were found to be directly and significantly correlated with quadriceps strength. Notably, a significant difference in quadriceps recovery and gait parameters was observed based on the type of ACL reconstruction performed. Patients undergoing reconstruction with an autologous patellar-ligament graft exhibited poorer outcomes compared to other surgical approaches.

Stevens, Mizner, & Snyder-Mackler, (2003) wanted to find out how arthrogenous muscle inhibition (AMI) contributes to thigh muscle weakness before and after TKA and how pain affects AMI. They tested 28 patients with severe knee arthritis, both before and after knee replacement surgery. Before surgery, the thigh muscles on the affected knee were weaker than the other knee. After surgery, thigh muscle strength significantly dropped by 60%, and same to activation decreased by 17%. Changes in muscle activation explained 65% of the change in thigh muscle strength.

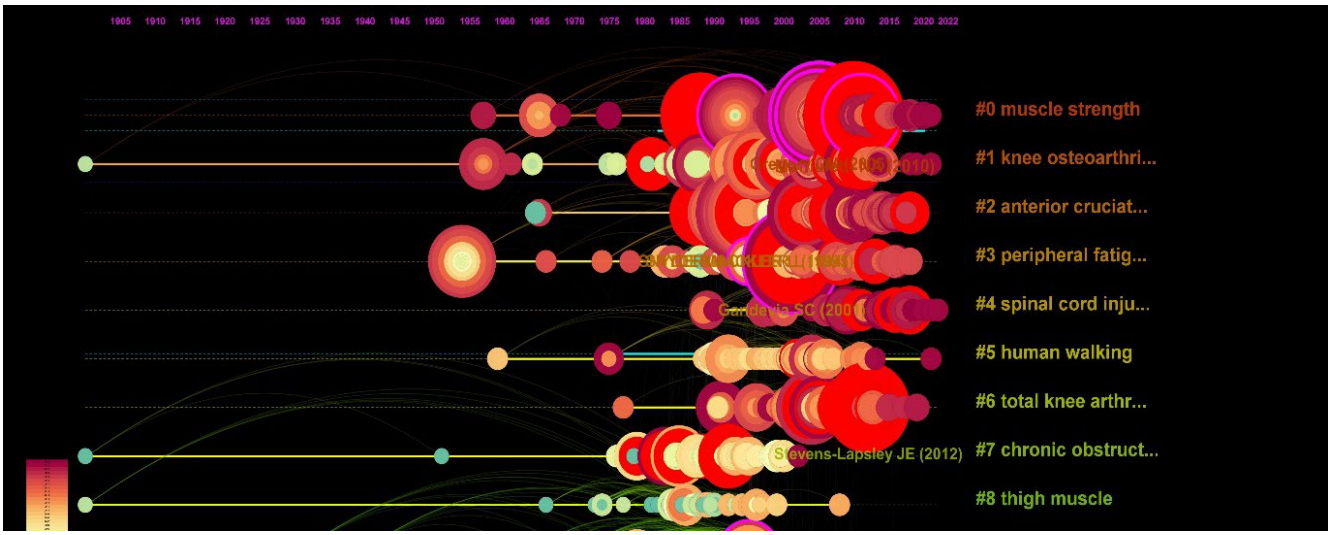

Figure 7: The ten most significant identified clusters. CiteSpace generated label

Knee pain during muscle contraction played a small but significant role in the change in muscle activation. To help patients with knee arthritis get stronger after knee replacement surgery, it is proposed to use exercise programs that focus on strong muscle contractions. Tools like biofeedback and electrical stimulation could also be useful. The study suggests that the current rehab methods might not be doing enough to address muscle activation problems right after surgery, which could be why thigh muscle weakness persists.

Concurrently, Seyedin et al., (2015) elucidate an upscaled production methodology for electrically conductive and remarkably stretchable PU/PEDOT:PSS fibers. The feasibility of an all-polymeric knitted textile wearable strain sensor is demonstrated through the fabrication of a knee sleeve prototype, highlighting its prospective application in personalized training regimens and post-injury rehabilitation efforts. These fibers exhibit mechanical characteristics conducive to the fabrication of diverse textile configurations via knitting techniques. In tandem with a wireless transmitter, the knitted textile adeptly responds to bending deformations, thereby showcasing promising avenues for remote strain sensing applications.

Snyder-Mackler et al., (1995) and Stevens et al., (2003) both concentrate on knee rehabilitation, while Seyedin et al., (2015) explores knitted textile wireless sensor transmitters, specifically demonstrating the feasibility of wireless strain sensing in a knee sleeve. Among these three, Snyder-Mackler et al., (1995) holds the highest prominence due to its earlier publication in 1995, making it more widely available in databases compared to the works of Stevens et al., (2003) and Seyedin et al., (2015).

Dominant topics/clusters and their temporal evolution

A short review of each cluster is done based on the highest number of publications of each cluster (>50 articles). Cluster with “muscle strength” was the largest cluster and had 126 publications and the most relevant article that cited this cluster is the review published by Maffiuletti, (2010). In the review, he believes that a comprehensive understanding of the physiological and methodological aspects of Neuromuscular Electrical Stimulation (NMES) enables the optimization of its application in clinical and research settings. By leveraging this knowledge, end users can strategically address the limitations and unique features of NMES to enhance its effectiveness and safety.

The second largest cluster is knee osteoarthritis with 98 articles and the most relevant citation to this cluster is the study by Kent-Braun & Le Blanc, (1996). They investigated central activation failure during maximal voluntary contractions (MVCs) in individuals experiencing muscle fatigue or neuromuscular disease. The findings indicate that a superimposed high-frequency train of stimuli is a more sensitive indicator of central activation failure during isometric MVCs compared to single or double stimuli methods. Anterior Cruciate Ligament is the third largest cluster with a total of 96 articles associated, and the study by Snyder-Mackler et al., (1995) is the most relevant citation in this cluster. The study was revealed as having the highest citation count.

Impactful publications and keywords for these areas

Based on the analysis of the co-citation network's document cluster, our investigation identified four pivotal publications and associated keywords pertaining to electrical modalities in knee rehabilitation. Notably, the studies authoured by Maffiuletti (2010), Stevens-lapsley,

Balter, Wolfe, Eckhoff, & Kohrt (2012), and Hermens et al. (2000) were selected based on their prominence in citation counts and burst metrics. Maffiuletti's review (2010) on neuromuscular electrical stimulation (NMES) gained traction particularly from 2017 to 2023, significantly influencing the emergence of a prominent cluster focusing on muscle strength. Stevens-lapsley et al.'s investigation (2012) explored the effects of early NMES application on quadriceps muscles post-total knee arthroplasty (TKA). Their findings underscored the efficacy of integrating NMES into rehabilitation protocols initiated 48 hours post-TKA, alongside standard interventions, in mitigating quadriceps muscle atrophy and enhancing functional outcomes. The study emphasised the pronounced and enduring benefits observed within the initial month following surgery, with sustained improvements evident up to one-year post-procedure. Meanwhile, Hermens et al. (2000) elucidated recommendations concerning surface electromyography (SEMG) sensors and their placement procedures, emphasising standardisation efforts and the ongoing nature of this endeavor. Their work has contributed significantly to establishing a comprehensive knowledge base regarding SEMG sensors and associated placement protocols, providing practical guidelines for the judicious utilisation of SEMG technology. The identified publications exemplify how seminal works shape the understanding and application of electrical modalities in knee rehabilitation. They provide both a historical context and a roadmap for future research, emphasising the intersection of innovation, evidence-based practice, and clinical efficacy. By analyzing these key studies, the investigation not only maps the field's intellectual structure but also highlights areas for further exploration, ensuring sustained progress in rehabilitation sciences.

The limitation of this study is that the analysis was conducted using only articles indexed in the Scopus database. As a result, relevant publications available in other databases such as Web of Science, PubMed, or non-indexed regional journals may not have been included. This could lead to a potential omission of studies, particularly those published in niche or less-cited sources, which might impact the comprehensiveness of the findings.

Future studies should integrate both Scopus and Web of Science databases to ensure a more comprehensive and reliable bibliometric analysis, as suggested in Azizan (2024). This approach addresses database-specific limitations, enhancing the coverage and accuracy of research trends. Additionally, Azizan (2024) also utilised a more comprehensive scoping review methodology, combining it with bibliometric analysis to provide deeper insights and a broader perspective on the research landscape. Similar methodologies were employed in other works by Azizan (2024), which demonstrate the importance of integrating bibliometric analysis with systematic or scoping reviews to identify research gaps, emerging trends, and future directions. This combined approach not only strengthens the rigor of bibliometric studies but also ensures a holistic understanding of the studied fields.

CONCLUSIONS

In conclusion, the scientometric analysis of electrical modalities for knee rehabilitation reveals a dynamic and growing field of research. The evolution of publication trends indicates a substantial increase in output, with notable contributions from key authors and institutions. The identified clusters, particularly "muscle strength," "knee osteoarthritis," and "anterior cruciate ligament," underscore critical areas of focus in the research landscape. The impact of publications, such as Maffiuletti, (2010) , Stevens-lapsley et al., (2012), and Hermens et al (2000), reflects the significance of studies on Neuromuscular Electrical Stimulation (NMES), early post-surgery interventions, and standardisation efforts in surface electromyography (SEMG) sensors, respectively. The findings provide a road map for future research directions, highlighting potential gaps and opportunities. The decrease in publications in 2023 prompts further exploration, and the identified clusters offer valuable insights for researchers seeking to contribute meaningfully to the field. As the scientometric analysis sheds light on influential publications and clusters, it lays the foundation for a more informed and strategic approach to advancing knowledge in electrical modalities for knee rehabilitation.

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Supplementary Tables

Table 1: Overview of techniques and tools used to answerthe research questions

ID	Research Question Focus	Software	Summary of techniques/ tools
RQ1	Publication output trends	Excel	Descriptive Analysis for number of publications, published journals, authors, universities/institutes, country/region, citation.
RQ2	Dominant knowledge carriers	CiteSpace	Co-citation Analysis for author to determine development status and scientific structure for each variable
RQ3	Dominant topic/cluster	CiteSpace	Document Cluster Analysis to identify the tip cluster of research in focus areas.
RQ4	Impactful publications and keyword	CiteSpace	Burstness metric used to determine the Influential publications and top keywords.

Table 2: The top ten articles publications

Title	Authors	Publication Year	Clinical Implication	Total Citation
Strength of The Quadriceps Femoris Muscle And Functional Recovery After Reconstruction Of The Anterior Cruciate Ligament - A Prospective, Randomized Clinical-Trial Of Electrical-Stimulation	Snyder-Mackler, Delitto, Bailey, & Stralka	1995	• High-intensity electrical stimulation improves quadriceps strength post-surgery. • Recovery varies based on surgical technique used.	304
Quadriceps Strength and Volitional Activation Before and After Total Knee Arthroplasty For Osteoarthritis	Stevens, Mizner, & Snyder-Mackler	2003	• neuromuscular electrical stimulation (NMES) and biofeedback to enhance muscle activation and strength. • Addressing these neuromuscular deficits early in the rehabilitation process may improve functional outcomes and expedite recovery.	275
Knitted Strain Sensor Textiles of Highly Conductive All-Polymeric Fibers	Seyedin et al.,	2015	• Remote body movement measurement using knitted textile sensors. • High sensitivity and stability for strain sensing applications.	245
Quadriceps Femoris Muscle Weakness and Activation Failure In Patients With Symptomatic Knee Osteoarthritis	Lewek, Rudolph, & Snyder-Mackler,	2004	• Both muscle strength and activation deficits is crucial in the management of knee OA to improve patient outcomes and quality of life.	238
Improved Function from Progressive Strengthening Interventions After Total Knee Arthroplasty: A Randomized Clinical Trial With An Imbedded Prospective Cohort	Petterson et al.,	2009	• Progressive quadriceps strengthening, whether combined with NMES or not, enhances recovery after TKA. • These interventions lead to superior short- and long-term functional outcomes compared to conventional rehabilitation methods.	216

Electrical Stimulation: Can It Increase Muscle Strength And Reverse Osteopenia In Spinal Cord Injured Individuals?	Bélanger, Stein, Wheeler, Gordon, & Leduc,	2000	• ES could be successfully integrated into rehabilitation programs to improve muscle mass and strength. • Combining ES with weight-bearing activities or pharmacological interventions might have a more significant impact on bone density.	210
Cutaneous Reflexes During Human Gait: Electromyographic And Kinematic Responses To Electrical Stimulation	Zehr, Komiyama, ; Stein	1997	• Understanding cutaneous reflexes aids in gait rehabilitation strategies. • Enhances knowledge of muscle coordination during walking.	197
Home Based Neuromuscular Electrical Stimulation As A New Rehabilitative Strategy For Severely Disabled Patients With Chronic Obstructive Pulmonary Disease (COPD)	Neder et al.,	2002	• NMES could become an important tool in the rehabilitation of severely disabled patients with COPD, helping improve muscle strength and overall physical function. • Muscle weakness, NMES could help improve the quality of life and physical capacity, allowing COPD patients to better manage daily activities.	193
Agonist-Antagonist Active Knee Prosthesis: A Preliminary Study In Level-Ground Walking	Martinez-Villalpando & Herr,	2009	• Agonist-antagonist design mimics human knee mechanics. • Modest power requirements reduce battery size for prosthesis.	191
Exercise-Induced Hypoalgesia In Pain-Free And Chronic Pain Populations: State Of The Art And Future Directions	Rice et al.,	2019	• Exercise can be a valuable component of chronic pain management. • Tailoring exercise interventions to individual needs and monitoring responses are crucial for achieving optimal outcomes.	181

Table 3: Top 10 Authors co-citation score

Author	Degree	Centrality	Sigma
Fitzgerald GK	42	0.08	2.28
Duchateau J	65	0.07	1.91
Marsolais EB	27	0.07	1.81
Bindermacleod SA	65	0.11	1.75
Delitto A	43	0.1	1.65
Biglandritchie B	56	0.05	1.52
Maffiuletti NA	37	0.05	1.49
Hurley MV	42	0.07	1.48
Hainaut K	39	0.05	1.47
Gregory CM	46	0.07	1.45

Table 4: Top 10 Major Cluster generated from Document Co-citation Analysis.

ClusterID	Size	Silhouette	Label (LLR)	Average Year
0	126	0.889	muscle strength (291.12, 1.0E-4)	2004
1	98	0.874	knee osteoarthritis (522.7, 1.0E-4)	1998
2	96	0.897	anterior cruciate ligament reconstruction (409.75, 1.0E-4)	2005
3	74	0.927	peripheral fatigue (404.25, 1.0E-4)	2001
4	72	0.933	spinal cord injury (129.34, 1.0E-4)	2012
5	60	0.949	human walking (127.57, 1.0E-4)	2000
6	55	0.925	total knee arthroplasty (439.91, 1.0E-4)	2005
7	51	0.93	chronic obstructive pulmonary disease (132.96, 1.0E-4)	1987
8	50	0.962	thigh muscle (116.21, 1.0E-4)	1985

Table 5: Top 10 References with the Strongest Citation Burst

Title	Year	Strength	Begin	End	1983 - 2023
Physiological and methodological considerations for the use of neuromuscular electrical stimulation	2010	11.85	2017	2023	
Early Neuromuscular Electrical Stimulation to Improve Quadriceps Muscle Strength After Total Knee Arthroplasty: A Randomized Controlled Trial	2012	11.54	2013	2020	
Development of recommendations for SEMG sensors and sensor placement procedures	2000	9.39	2017	2023	
Statistical Power Analysis for the Behavioral Sciences	1988	8.11	2016	2023	
Spinal and supraspinal factors in human muscle fatigue	2001	7.94	2016	2019	
Motor unit recruitment during neuromuscular electrical stimulation: a critical appraisal	2011	7.88	2014	2023	
Early Quadriceps Strength Loss After Total Knee Arthroplasty: The Contributions of Muscle Atrophy and Failure of Voluntary Muscle Activation	2005	7.13	2012	2016	
Neuromuscular electrical stimulation for quadriceps muscle strengthening after bilateral total knee arthroplasty: a case series	2004	7.03	2007	2015	
Improvement in Isometric Strength of the Quadriceps Femoris Muscle After Training with Electrical Stimulation	1985	6.75	2000	2007	

Strength of the quadriceps femoris muscle and functional recovery after reconstruction of the anterior cruciate ligament. A prospective, randomized clinical trial of electrical stimulation.	1995	6.75	2011	2014	

ORIGINAL ARTICLE

Comparison Between the Effect of Free Weight and Machine Exercise on the Quadriceps Muscles Among Male Students in IIUM Kuantan

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ABSTRACT

Background: Exercise, particularly resistance training, plays a crucial role in an individual's overall fitness. This research aimed to compare the efficacy of free-weight (FW) versus machine-based (MB) resistance training towards the changes in quadriceps muscle girth among the male students at the International Islamic University Malaysia (IIUM) Kuantan. **Methods:** Twenty-four (N=24) male students (age range) were selected and underwent an eight-week resistance training program. Participants were divided into FW (n=12) and MB (n=12) training groups. Participants trained twice weekly, and quadriceps muscle girth were measured using a measuring tape at week four (W4) and eight (W8). **Results:** Quadriceps size significantly increased with both free weights (52.74±3.22 to 54.43±3.24) and machines (52.66±5.48 to 54.35±5.40) over 4 and 8 weeks ($p < 0.001$). **Conclusion:** FW and MB were beneficial for individuals seeking to improve their quadriceps muscle size changes following eight weeks of training.

INTRODUCTION

Many exercises have been introduced, and each of the exercises targets different muscle groups. Most of the exercise can be performed using free weights and machine equipment. Nevertheless, most people still query which of the resistant exercises can be performed to reach their goals, since both offer advantages and disadvantages of their own. At the gym, questions arise on which of the exercises should be added to the regime to achieve specific muscle group hypertrophy. Aerenhouts and D'Hondt (2020) reported that regardless of whether adult male novices in resistance training use machines (M) or free weights (FW), they can expect significant positive training effects within a 10-week period. Furthermore, transitioning from machines to free weight exercises does not result in a decline in progress. Both machine and free weight exercises increase muscle strength in 10-week periods, but there is no clear evidence that muscle size can increase under a 10-week timeframe and which one can contribute more in terms of muscle size. On the other hand, a study by Schoenfeld et al. (2019) found that resistance-trained individuals can significantly improve strength and endurance through just three 13-minute weekly sessions over an 8-week duration. Thus, this study seeks to explore whether muscle size can increase within a 4 to 8-week time frame and perhaps be able to increase muscle strength and endurance by following the correct training plan. It is essential to achieve this objective as it can improve the knowledge of exercise using free weights and machines. It is also important as the quadriceps are used in most daily movements and physical activities. Moreover, the quadriceps also the most useful muscles in the human body, as they never rest in doing their movement, which is knee extension in daily routine.

MATERIALS AND METHODS

Study Design

This study implemented a quasi-experimental study design to investigate the effect of different modes of resistance training programs (FW or MB) on the changes in quadriceps muscle girth measurement.

Participants

The purposive sampling method was utilised to recruit (N=24) participants who met the inclusion and exclusion criteria. The study involved IIUM Kuantan male students aged 18–25 years, weighing 50–80 kg, who were healthy and free from lower limb musculoskeletal injuries. Exclusion criteria include physical illnesses aggravated by

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exercise, previous knee injuries, regular gym-goers, and those taking protein supplements, ensuring uniformity in dietary intake among participants.

Resistance Training Program

The study was conducted at the IIUM in Kuantan. Participants were randomly divided into two groups of 12, assigned to either free weight or machine exercises, with no control group. The free weight group performed squats, while the machine group used the quadriceps bench. The training programme lasted for 8 weeks, with both groups exercising twice weekly using weights set at 12-RM, a standard load for beginners that can be lifted correctly up to 12 repetitions. Each session consisted of three sets per exercise. A trained researcher supervised all sessions to ensure proper technique and adherence to the protocol.

Quadriceps Muscle Girth Measurement

Quadriceps girth was measured at 18 cm above the anteromedial knee joint line using a measuring tape. Initial measurements were taken with participants in a supine position before the programme began, after obtaining informed consent. Subsequent measurements were conducted at the start of the 4th and 9th weeks using the same methodology to maintain consistency. Data were recorded systematically and analysed using SPSS to ensure accurate and reliable results.

Sample Size Calculation

A priori power analysis was calculated using G-power software version 3.0, which revealed that 24 participants were required to achieve a statistical power of 80% at a significant level of $p<.05$, with the effect size of 0.25 (Aerenhouts & D'Hondt, 2020). Therefore, the participants were equally assigned to FW (n=12) and MB (n=12) resistance training groups.

Ethical Consideration

This study was approved by IIUM's research ethics committee (reference no.: IIUM/504/14/11/2/IREC 2023-KAHS/DPRS) to ensure adherence to ethical standards and the protection of participants' rights throughout the study. Ethical considerations were followed throughout the study, including ensuring participant confidentiality and obtaining the necessary approvals. They were thoroughly briefed on the study's objectives, their right to decline participation at any point, and strict confidentiality measures in place for the collected data. Participants' written informed consent was obtained before embarking on the study.

Statistical Analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS) Version 12. The statistical tool employed was a paired sample t-test to elucidate the effectiveness of a resistance training program (FW or MB) on quadriceps muscle girth changes. An independent sample t-test was also conducted to compare the effect of different modes of resistance exercises (FW and MB) on quadriceps muscle girth changes in the 4th and 8th weeks, respectively.

RESULTS

The study included 24 male undergraduate students from the International Islamic University Malaysia (IIUM) in Kuantan, Pahang, aged between 18 and 25 and weighing 50–80 kg. Participants were divided equally into two groups, with 12 individuals undergoing free-weight (FW) resistance training and performing machine-based (MB) resistance training from week 4 to week 8.

Effects of Free Weight versus Machine-Based Resistance Training on Different Weeks of Training

Significant improvement was observed in both free-weight and machine exercise from week 4 to week 8. For free-weight resistance training, the quadriceps girth increased from 52.74 ± 3.22 cm at week 4 to 54.43 ± 3.24 cm at week 8. For machine exercises, the quadriceps girth improved from 52.66 ± 5.48 cm at week 4 to 54.35 ± 5.40 cm at week 8 (Table 1).

Effect of Different Resistance Training Modes on Different Weeks of Training

In comparing free-weight and machine exercise at respective weeks, there are no significant differences in the mean comparison between free-weight exercise (54.43 ± 3.24) and machine exercise (54.35 ± 5.40) in the week 4th and 8th of training, respectively (Table 2).

DISCUSSION

The current study demonstrated that both resistance training modes contributed to significant quadriceps girth increments following training. Therefore, achieving the desirable results within an eight-week time frame is possible. Different resistance exercise modes must align with the goals of individuals seeking to increase the size of their quadriceps muscles. Individuals with the aim of improving general fitness and aiming for similar

outcomes can opt for the MB resistance training program because of its user-friendly nature and convenience while avoiding the complexities associated with moving plates. This makes them accessible to people of all fitness levels, including newbies who might be less familiar with exercise techniques. Exercise using machines also can isolate muscle groups more effectively (Bergeron, 2022). On the other hand, experienced gym-goers may include squats in their workout regimen, which requires precise biomechanics and adherence to safety measures. Moreover, FW exercise is more flexible since it can be used anywhere. According to Wilke et al. (2020), free weights offer the flexibility of training anywhere as they require minimal equipment and do not rely on specific machines.

The results indicate comparable improvements in quadriceps size for both free weight and machine-based exercises during the 4th and 8th weeks of training. This is better than the observation by Aerenhouts and D'Hondt (2020), who reported that adult male novices in resistance training, regardless of whether they utilise machine (M) or free-weight (FW) exercises, can expect significant positive training effects within a 10-week period. In addition, the notion that free-weight exercises result in a faster increase in quadriceps size than machine exercises is dismissed.

Instead, we believed a blended approach incorporating FW and MB resistance training might add variety to the workout routine while ensuring consistent improvement in quadriceps size over eight weeks of the training period. Nevertheless, this requires further testing in different settings. Furthermore, this study indicates that individuals with limited time to go to the gym can use FW resistance training, such as squats or weighted squats, at home to optimise muscle hypertrophy by using the weight they can lift for twelve reps, as demonstrated in this study.

The weight does not require a barbell; athletes can use sufficient tools, such as bottled water and other weights, to increase the mechanical stress of the exercise. If the individual only has limited time to train in the gym, they can use a quad bench instead. Since both exercises can improve the quadriceps muscle, there should be no problem in maximising the use of each resistance exercise to their own benefit.

CONCLUSION

Significant improvement was observed as the participants experienced increased muscle girth compared to the initial week. On the other hand, there were no noticeable differences in comparing modes of resistance training (FW or MB). Furthermore, both forms of exercise prove beneficial for hypertrophy when performed correctly, highlighting consistent size gains during the 4th and 8th weeks of training.

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Table 1: The effect of resistance training on the changes of quadriceps muscle girth in weeks 4 and 8

Resistance Training	4th Week		8th Week		Mean Differences (95% CI)	t-statistic (df)	*p*-value
	Mean	S.D	Mean	S.D			
Free-weight	52.74	3.22	*54.43	3.24	-1.691 (-2.04, -1.33)	-10.4 (11)	0.000
Machine Exercise	52.66	5.48	*54.35	5.40	-1.691 (-1.99, -1.38)	-12.07 (11)	0.000

Table 2: Comparing the size of quadriceps (cm) in the 4th and 8th week of training between free weight (n=12) and machine (n=12)

Resistance Training	Free Weight		Machine Exercise		Mean Differences (95% CI)	t-statistic (df)	*p*-value
	Mean	S.D	Mean	S.D			
4th Week	52.74	3.22	52.66	5.48	0.083 (-3.72, 3.89)	0.045 (22)	0.964
8th Week	54.43	3.24	54.35	5.40	0.083 (-3.69, 3.85)	0.046 (22)	0.964

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REVIEW ARTICLE

A Meta-Meta-Analysis of The Impact of COVID-19 on Pregnant Women

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ABSTRACT

Background: Many studies have examined the effects of COVID-19 on pregnant women. Providing comprehensive evidence on the physical, psychological, and fetal effects, the knowledge gained can be applied to the care of pregnant women and their infants. This study aimed to conduct a meta-analysis on the impact of COVID-19 on pregnant women and their infants. **Methods:** This meta-analysis encompasses 21 meta-analyses identified via a search of electronic databases (PubMed, CINAHL). Meta-analyses have reported the effects of coronavirus disease 19 (COVID-19) on pregnant women and neonates. Analyses were based on random effects models. To combine the results, the effect estimates of the meta-analyses were transformed to SMD and weighted to correct primary study overlap, conducted by the PRISMA 2020 reporting guidelines, and the data were analyzed using the meta-analysis website. The meta-analyses sample included 21 meta-analyses (total number of studies k = 914, n = 3,936,822). **Results:** The effect of COVID-19 affected depression (EF = 21.74(95% CI 13.84 – 34.15) p <.01, I^2 = 97%, p <.01), anxiety (EF = 23.77(95% CI 14.71 – 38.42) p <.01, I^2 = 89%, p <.01. However, COVID-19 has not affected the health of pregnant women and infants. **Conclusion:** The findings of this study emphasize the importance of prioritizing the mental health of pregnant women affected by COVID-19 and offer valuable insights for public health officials regarding the necessity of addressing their mental well-being.

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic was caused by a novel coronavirus (SARS-CoV-2) and was a public health emergency of international concern. SARS-CoV-2 is an RNA virus responsible for causing COVID-19. Previous studies have shown that pregnant women infected with the novel coronavirus (SARS- CoV) are at high risk of developing adverse complications, with a high mortality rate. In pregnant women infected with the virus, the mortality rate is as high as 40% (Alfaraj et al. 2019), and we should be vigilant. Thus, there is the possibility of similar serious side effects in pregnant women infected with COVID-19. However, a Swedish study found that pregnant and postpartum women infected with COVID-19 may have a higher risk of being admitted to the intensive care unit (ICU) compared to non-pregnant women of the same age (Collin et al. 2020).

The impact of the COVID-19 outbreak has psychologically affected the mental health of pregnant women (Saccone et al. 2020). Pregnant women assessed during the COVID-19 pandemic reported higher distress and psychiatric symptoms than those assessed before the pandemic, most commonly depression and anxiety (Durankus and Aksu. 2022).

In addition, the COVID-19 pandemic has affected infants, with an increase in the number of infants diagnosed as small for gestational age (SGA), 5th minute Apgar score less than 7, and infants diagnosed with hypoxic-ischemic encephalopathy (Hekimoglu and Acar. 2022).

Although there are many meta-analyses of the effects of COVID-19, there is still no meta-analysis to provide comprehensive information on the physical, mental, and infant effects; therefore, the knowledge gained can be applied to the care of pregnant women and infants. This meta-meta-analysis aimed to determine the impact of COVID-19 on pregnant women and infants.

MATERIALS AND METHODS

Study Design

This was a systematic review and meta-analysis of all studies evaluating the impact of COVID-19 on pregnant women and infants.

Eligibility criteria

To select the papers, the following inclusion criteria were

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defined: (a) articles focused on the impact of COVID-19 on pregnant women, and (b) articles with meta-analysis research papers. We excluded review studies regarding other viruses in the coronavirus family (i.e. SARS-CoV-1, MERS-CoV) and reports on the effects on the unborn child.

Information sources

PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Scholar were searched up to 15th June 2024—research published in English. The research strategy adopted included different combinations of the following terms: "SARS-CoV-2", "COVID-19", "meta-analysis", and "pregnancy".

Manual searches included scanning reference lists of relevant papers and meta-analyses during the literature analysis.

Study selection

All studies identified through electronic database searches were systematically recorded, including citation details, titles, authors, and abstracts. To ensure accuracy, duplicates were identified and removed through a manual screening process that was independently conducted by two researchers. Any discrepancies were resolved through discussion or consultation with a third party. The quality of the included reviews was assessed using an abbreviated list of quality criteria extracted from PRISMA 2020 (Tsuge et al., 2024). A PRISMA 2020 flow diagram of the selection process is shown in Figure 1.

For the eligibility process, two authors (RG and DTF) independently screened the titles and abstracts of all non-duplicated papers and excluded those not pertinent to the topic. The same two authors independently reviewed the full text of documents that passed the first screening and identified those to be included in the review. Discrepancies were resolved by consensus.

Data extraction

Two researchers conducted data extraction using a predefined form to collect details such as author, study timing, location, design, and participant demographics. Outcomes of interest were categorised into two groups: psychological health, the mental health of women and the foetus.

Statistical analysis

In this systematic review and meta-analysis, the relative risk (RR) with a 95% confidence interval (CI) was employed to measure effect sizes across all included studies. The mean effect sizes and their corresponding 95% CIs, as reported in the original meta-analyses, were illustrated using forest plots. The standardized mean difference (typically d or g) was the most frequently reported effect size, and these measures were utilized to plot the effects. Data analysis was conducted using an online meta-analysis platform (https://metaanalysisonline.com/).

RESULTS

Figure 1 shows a flowchart of the study selection process. The literature search resulted identified 545 published papers. An additional 21 publications were identified through the reference search.

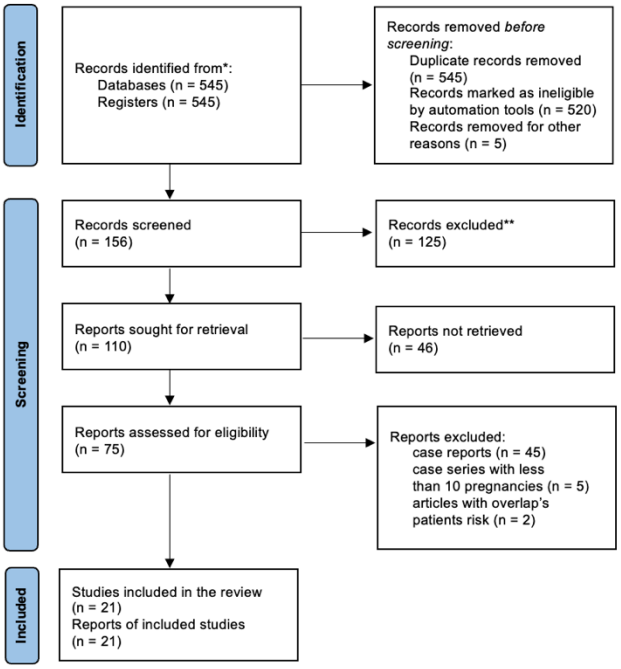

Figure 1: Flow diagram of meta-analyses

Participant Characteristics

The PRISMA 2020 flow diagram outlined the study selection process. Following the full-text screening, 21 systematic reviews were included. Our meta-analyses sample included 21 meta-analyses (total number of studies k = 914, n = 3,936,822). Fifteen studies reported physical effects and six reported psychological effects.

Study results and summary meta-analysis

The impact of COVID-19 on the health of pregnant women includes preeclampsia, gestational diabetes, lymphocytopenia, ICU admission, and death. It also affects the mental health of mothers. In addition, the effects on the infant included low birth weight, fetal distress, preterm birth, cesarean delivery, APGAR score < 7, NICU admission, and neonatal death**.**

A meta-meta-analysis of preeclampsia included seven studies on preeclampsia in women with COVID-19 (Figure 2). Heterogeneity for the two combined effect sizes was high (I^2 = 91%) and the summary effect size was not statistically significant [overall effect size = 1.71 (95% CI = 0.78, 1.76, p = 0.45)]. COVID-19 does not affect preeclampsia in pregnant women.

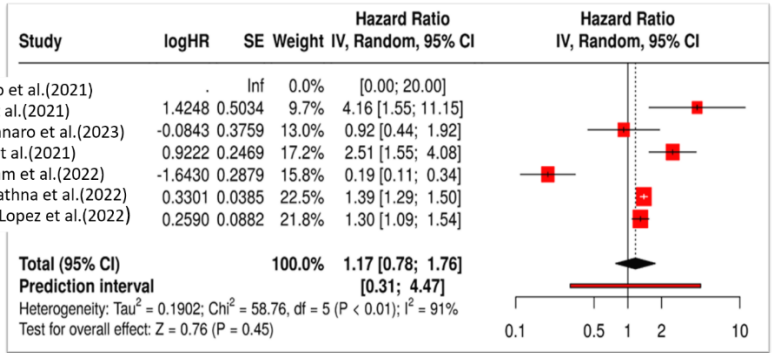

Figure 2: Meta-meta-analysis examining the association between COVID-19 and the risk of preeclampsia

Meta-meta-analysis of gestational diabetes included two studies on gestational diabetes in pregnant women with COVID-19 (Figure 3). Heterogeneity for the two combined effect sizes was high (I^2 = 81%) and the summary effect size was not statistically significant [overall effect size = 1.30 (95% CI = 0.63, 2.67, p = 0.48)]. COVID-19 does not affect gestational diabetes in pregnant women.

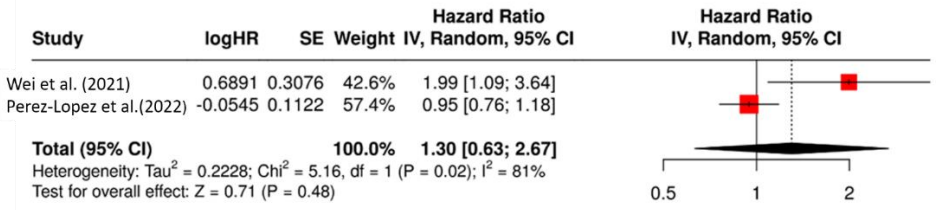

Figure 3: Meta-meta-analysis examining the association between COVID-19 and the risk of gestational diabetes

The meta-meta-analysis of lymphocytopenia included three studies on lymphocytopenia in pregnant women with COVID-19 (Figure 4). The combined effect sizes were highly heterogeneous (I^2 = 99%) and the summary effect size was not statistically significant (overall effect size = 3.48 (95% CI = 0.32, 37.30, p = 0.30)). COVID-19 does not affect lymphocytopenia in pregnant women.

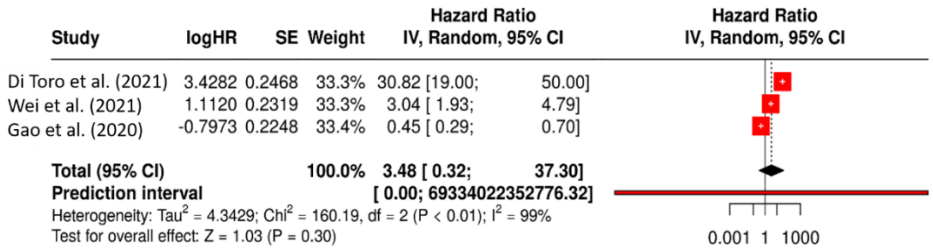

Figure 4: Meta-meta-analysis examining the association between COVID-19 and the risk of lymphocytopenia

Four studies reported ICU admissions in pregnant women with COVID-19 (Figure 5). The combined effect sizes were highly heterogeneous (I^2 = 96%) and the summary effect size was not statistically significant [overall effect size = 2.40 (95% CI = 0.66, 8.79, p = 0.19)]. COVID-19 does not affect ICU admission in pregnant women.

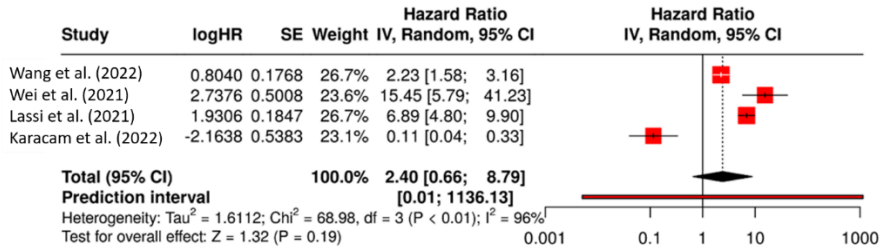

Figure 5: Meta-meta-analysis examining the association between COVID-19 and the risk of ICU admission

Nine studies reported maternal death in pregnant women with COVID-19 (Figure 6). The two combined effect sizes were highly heterogeneous (I^2 = 98%) and the summary effect size was not statistically significant [overall effect size = 0.55 (95% CI = 0.16, 1.84, p = 0.33)]. COVID-19 does not affect maternal death in pregnant women.

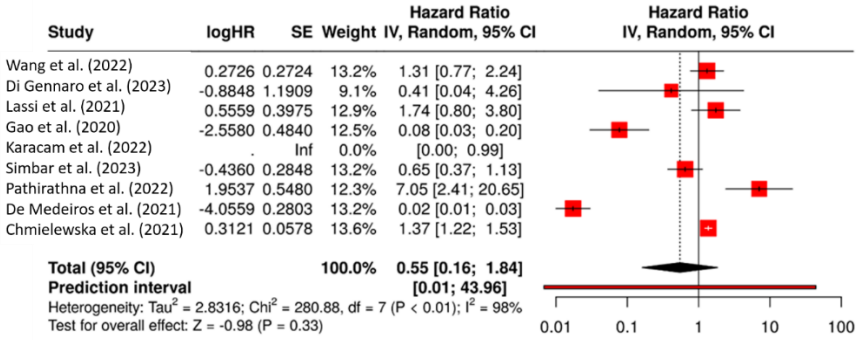

Figure 6: Meta-meta-analysis examining the association between COVID-19 and the risk of maternal death

Eleven studies reported cesarean deliveries in pregnant women with COVID-19 (Figure 7). The combined effect sizes were highly heterogeneous (I^2 = 100%) and the summary effect size was not statistically significant [overall effect size = 3.14 (95% CI = 0.82, 12.08, p = 0.10)]. COVID-19 does not affect cesarean delivery in pregnant women.

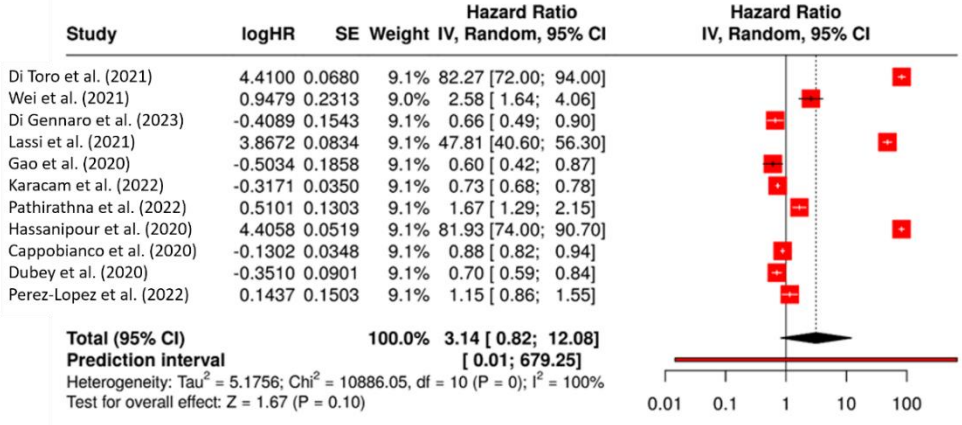

Figure 7: Meta-meta-analysis examining the association between COVID-19 and the risk of cesarean delivery

Five studies reported fetal distress in foetuses with COVID-19 (Figure 8). The combined effect sizes were highly heterogeneous (I^2 = 98%) and the summary effect size was not statistically significant (overall effect size = 0.43 (95% CI = 0.14, 1.32, p = 0.14)). COVID-19 does not affect fetal distress.

Twelve studies reported preterm births in foetuses with COVID-19 (Figure 9). The combined effect sizes were highly heterogeneous (I^2 = 99%) and the summary effect size was not statistically significant [overall effect size = 1.47 (95% CI = 0.54, 3.98, p = 0.45)]. COVID-19 does not affect preterm birth in the foetus.

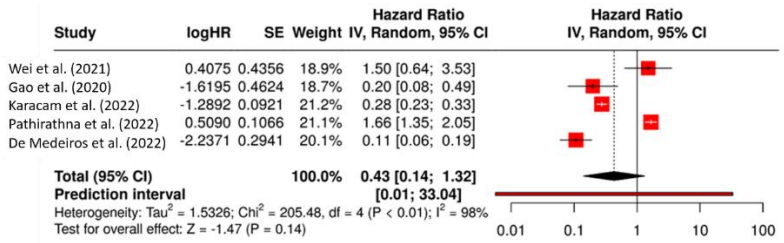

Figure 8: Meta-meta-analysis examining the association between COVID-19 and the risk of fetal distress

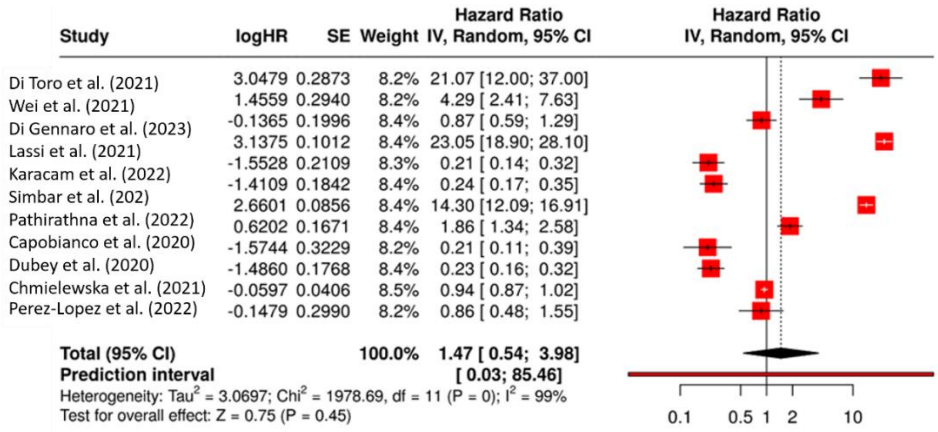

Figure 9: Meta-meta-analysis examining the association between COVID-19 and the risk of preterm birth

Six studies reported an APGAR score < 7 in foetuses with COVID-19 (Figure 10). The combined effect sizes were highly heterogeneous (I^2 = 98%) and the summary effect size was not statistically significant [overall effect size = 0.42 (95% CI = 0.11, 1.59, p = 0.20)]. COVID-19 infection did not affect the APGAR score of < 7 in the foetus.

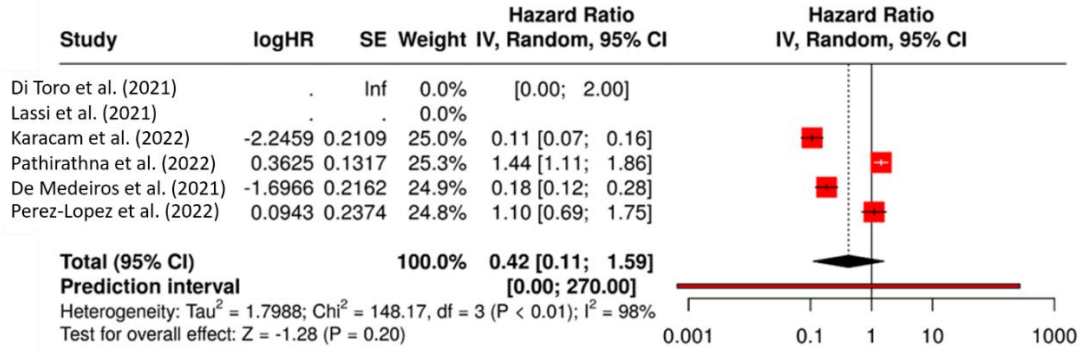

Figure 10: Meta-meta-analysis examining the association between COVID-19 and the risk of an APGAR score < 7

Birth weight < 2,500 g: Six studies reported birth weight < 2,500 g in foetuses with COVID-19 (Figure 11). The combined effect sizes were highly heterogeneous (I^2 = 99%) and the summary effect size was not statistically significant (overall effect size = 0.67 (95% CI = 0.15, 3.04, p = 0.61)). COVID-19 infection does not affect a birth weight of < 2,500 g in the foetus.

Ten studies reported NICU admission in foetuses with COVID-19 (Figure 12). The combined effect sizes were highly heterogeneous (I^2 = 98%) and the summary effect size was not statistically significant [overall effect size = 1.56 (95% CI = 0.46, 5.30, p = 0.47)]. COVID-19 does not affect NICU admission to the foetus.

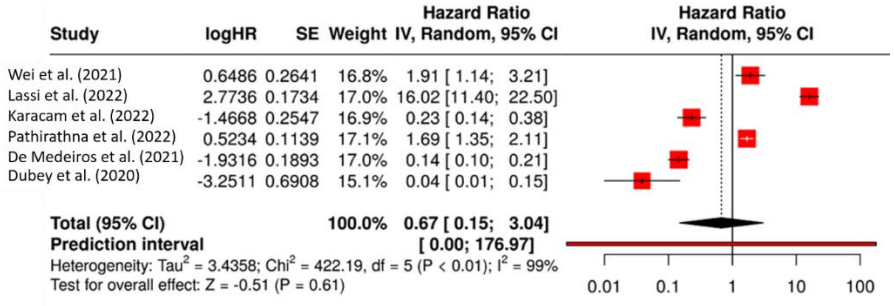

Figure 11: Meta-meta-analysis examining the association between COVID-19 and the risk of birth weight < 2,500 g

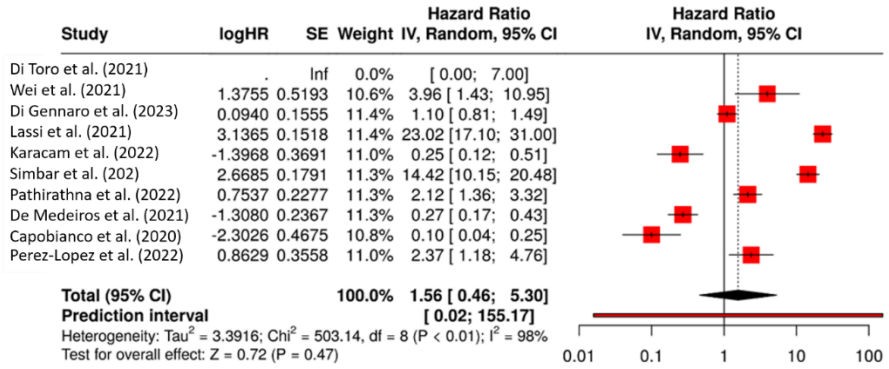

Figure 12: Meta-meta-analysis examining the association between COVID-19 and the risk of NICU admission

Ten studies reported neonatal deaths in foetuses with COVID-19 (Figure 13). The combined effect sizes were highly heterogeneous (I^2 = 95%) and the summary effect size was not statistically significant (overall effect size = 0.80 (95% CI = 0.43, 1.47, p = 0.47)). COVID-19 does not affect neonatal death in foetuses.

The impact of COVID-19 on the mental health of pregnant women included depression and anxiety. Five studies reported depression in pregnant women with COVID-19 (Figure 14). The combined effect sizes were highly heterogeneous (I^2 = 97%) and the summary effect size was statistically significant [overall effect size = 21.74 (95% CI = 13.84, 34.15, p < 0.01)]. COVID-19 affects depression in pregnant women.

Six studies reported on anxiety in women with COVID-19 (Figure 15). The combined effect sizes were highly heterogeneous (I^2 = 89%) and the summary effect size was statistically significant [overall effect size = 23.77 (95% CI = 14.71, 38.42, p < 0.01)]. COVID-19 affects anxiety in pregnant women.

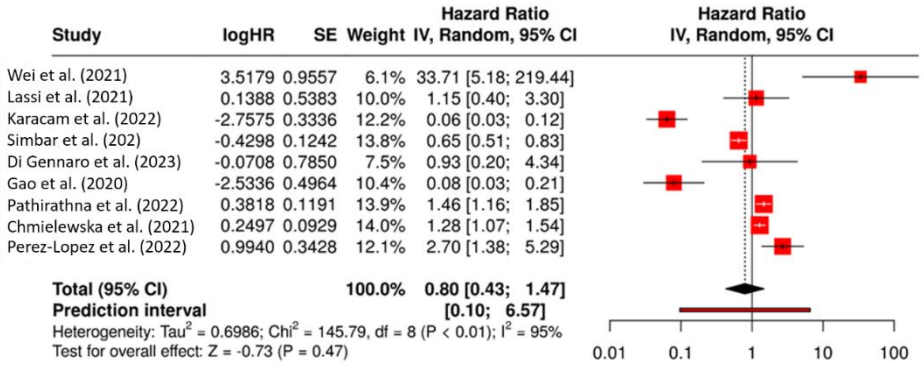

Figure 13: Meta-meta-analysis examining the association between COVID-19 and the risk of neonatal death

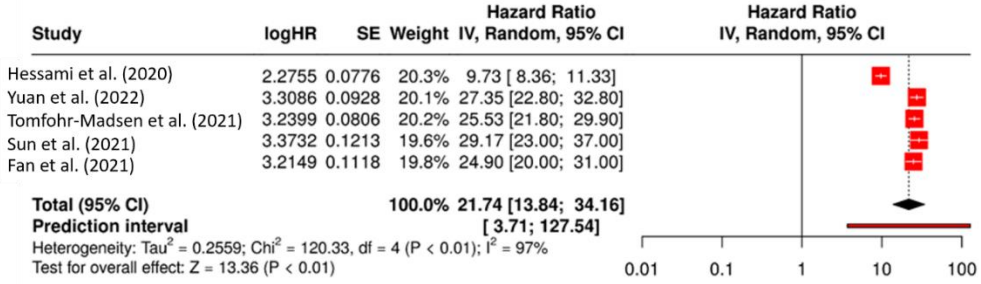

Figure 14: Meta-meta-analysis examining the association between COVID-19 and the risk of depression

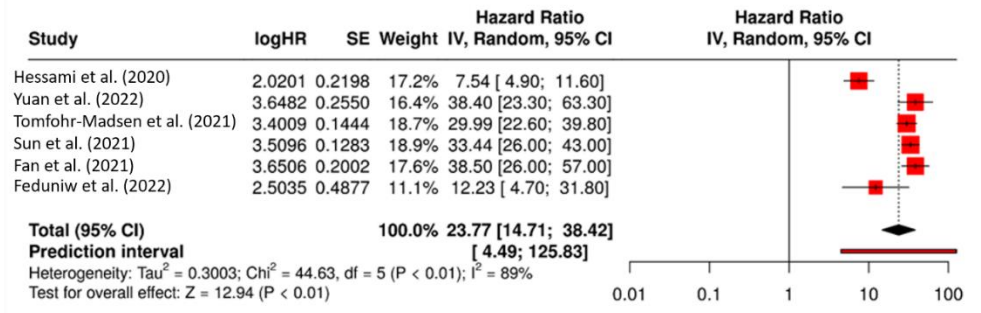

Figure 15: Meta-meta-analysis examining the association between COVID-19 and the risk of anxiety

In summary, COVID-19 infection during pregnancy was associated with anxiety and depression in pregnant women but was not associated with physical morbidity of the mother and foetus, such as ICU admission and mortality. Addressing these challenges require adapting healthcare delivery, enhancing mental health resources, and providing robust support systems to help pregnant women navigate the unprecedented period. This heightened mental health burden is often linked to fears of health risks, disruptions in prenatal care, and social isolation. Depression and anxiety in pregnant women are associated with potential adverse effects on foetal development.

This included concerns about preterm birth and low birth weight, although evidence is still emerging. Enhanced prenatal monitoring, including regular check-ups and appropriate testing, can help manage potential complications. Early identification and intervention are crucial to mitigate the risks associated with COVID-19 during pregnancy. Providing comprehensive care and support, including mental health resources and guidance on infection control, helps to address the broader impact of the pandemic on pregnant women.

DISCUSSION

This study conducted a meta-analysis on the impact of COVID-19 on pregnant women and their infants. Our results indicate that COVID-19 has a statistically significant impact on the mental health of pregnant women. This leads to stress and depression. This result is consistent with the findings of Tomfohr-Madsen et al. (2021), who found that the prevalence of anxiety was higher in studies conducted later in the pandemic. The post-pandemic period has seen an increase in anxiety, which may be linked to chronic stress exposure during the pandemic and ongoing uncertainty. Hessami et al. (2022) found that the COVID-19 pandemic significantly increases the risk of anxiety among women during pregnancy and the perinatal period. Other studies have shown that pregnant women reported increased anxiety and depressive symptoms during the pandemic, with some experiencing PTSD (Savenysheva et al., 2024; Zhou et al., 2024). Research indicates that 53% of pregnant women encounter the psychological impact as severe (Saccone et al., 2020).

Pregnant women are inherently more vulnerable to emotional distress, and the uncertainty surrounding COVID-19 intensifies these feelings (Cigăran et al., 2024). Sun et al. (2021) found a higher prevalence of depression, anxiety, and depression in pregnant and delivery women during the COVID-19 pandemic. Factors such as hospitalisation due to COVID-19 are significantly correlated with worsened mental health outcomes (Cigăran et al., 2024). Owing to the COVID-19 outbreak, pregnant women must be quarantined and separated from their families. Thinking about illness concerns about a disease and illness in an unborn child. The COVID-19 pandemic has significantly affected the mental health of pregnant women, leading to increased anxiety and depression during the perinatal period. Research indicates that lockdowns and associated stressors exacerbate preexisting vulnerabilities, necessitating targeted support measures for this high-risk population.

The psychological impact of COVID-19 on pregnant women has highlighted their vulnerability, necessitating ongoing evidence-based screening and treatment of depression and anxiety. Research indicates that the pandemic has exacerbated mental health issues in this population, with significant rates of anxiety and depression reported. The physical impact on the pregnant women and infants was not substantial. Studies have shown significantly reduced risks of severe outcomes, including hospitalization, ICU admission, oxygenation, mechanical ventilation, and mortality for Omicron compared to other variants such as Delta. Omicron's hospitalization rate was lower than that of Delta (Arabi et al., 2023). The mortality rate for Omicron infections ranges from 0.01% to 13.1%, notably lower than the 0.08% to 29.1% observed with earlier variants ("The disease severity of COVID-19 caused by Omicron variants: A brief review," 2023).

The research report was synthesized from the period when the COVID-19 vaccine was administered to pregnant women. This result is consistent with the findings of Ciapponi et al. (2024), who found low to very low certainty evidence suggesting that vaccination during pregnancy with mRNA vaccines may reduce severe cases or hospitalisations in pregnant persons with COVID-19, symptomatic COVID-19, and virologically confirmed SARS-CoV-2 infection. Hybrid immunity from vaccinations and previous infections has contributed to milder outcomes associated with Omicron (Shervani et al., 2022). Vaccination, particularly booster doses, has been shown to enhance protection against severe illnesses from Omicron (Arabi et al., 2023). Although Omicron is generally less severe, it still poses risks, especially for high-risk populations. The ongoing evolution of the virus and its variants necessitates continued monitoring and research to fully understand their implications (Parise et al., 2023). The administration of COVID-19 vaccines during pregnancy has been shown to significantly reduce the risk of severe COVID-19 and its associated adverse outcomes in both mothers and their offspring.

LIMITATION

A limitation of this study was that the data extracted from all the studies were collected retrospectively. Patient information regarding secondary outcomes was missing or unavailable in many studies. Future research should explore increased screening for depression and stress in pregnant women and develop programs to reduce depression and stress in pregnant women.

CONCLUSION

Our study underscores the critical need to prioritize the mental health of pregnant women impacted by the COVID-19 pandemic. Despite the evident importance of this issue, research remains limited, leaving significant gaps in understanding the unique psychological challenges faced by this vulnerable population and the development of effective intervention strategies. The study aims to bridge these gaps by offering valuable insights for public health officials to design targeted mental health support initiatives for pregnant women during the pandemic. It contributes to the broader understanding of mental health by illustrating its profound implications on pregnancy outcomes. Findings reveal that the COVID-19 pandemic has exacerbated anxiety symptoms among pregnant women, a group already predisposed to mental health vulnerabilities. Elevated anxiety levels during this period were primarily driven by concerns related to maternal and foetal health, restricted access to prenatal care, and heightened social isolation. These results highlight the need for healthcare systems to adopt proactive and adaptive strategies to address mental health challenges among pregnant women. Such adaptations should ensure adequate support for this population, regardless of external stressors, to mitigate the adverse effects on maternal well-being and pregnancy outcomes.

ACKNOWLEDGEMENT

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REVIEW ARTICLE

Mesenchymal Stem Cell-Derived Exosomes and Treatment in Atherosclerosis: A Scoping Review

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ABSTRACT

Atherosclerosis is an inflammatory disease that involves the formation of plaque in large arteries. It is a leading cause of vascular death worldwide, and current therapy is not effective for all patients. Recently, mesenchymal stem cell-derived exosome particles have shown potential as treatment for this disease. Therefore, this scoping review is to provide an overview and determines the extent of research on its potential for use as treatment in atherosclerosis. For article search, five online databases were used, namely Scopus, Science Direct, Cambridge Journal, PubMed, and Cochrane Library. Keywords (atherosclerosis OR atherogenesis) AND ('mesenchymal cell' OR 'stem cell') AND (exosome OR exosomes) were used. After the screening steps, irrelevant articles were removed and the final retrieval steps provided 10 full-text articles to be reviewed. The summary of the core concepts that were used in all relevant articles showed that inflammation is the most targeted process in this disease development followed by inhibition of apoptosis and facilitation of movement of cells that contributes to the atherogenesis. In most papers, exosomes from mesenchymal stem cells were used as vehicles to transport biological components to the targeted site, in vitro or in vivo. Only one paper reported on the antiatherogenic effect of exosomes in vivo. Several issues remain to be elucidated, such as the best method to extract the exosomes, their specific component that promotes antiatherogenic effects, their interaction with the inflammatory and immune cells, the optimum level needed for intervention and their stability once injected in vivo. In conclusion, there are a lot of research gaps that should be addressed in order to use exosomes from mesenchymal cells in atherosclerosis treatment.

INTRODUCTION

Atherosclerosis is the main cause of cardiovascular disease. This disease is the leading cause of death in Malaysia in 2021, where it contributed to 17% of the total deaths of the population (Department of Statistic, 2022). Atherosclerosis involves chronic inflammation that leads to the formation of plaque in the major artery wall (Lu et al., 2019). The atherosclerotic plaque could rupture and cause an atherosclerotic stroke. Atherogenesis involves interaction between inflammatory cytokines, smooth muscle cells and macrophages. The presence of ox-LDL is also one of the important key triggers for atherogenesis (Lu et al., 2019). Ox-LDL is formed when its lipid components, such as polyunsaturated fatty acids are oxidized by reactive oxygen species (Munno et al. 2024).

Despite the advancements in medicine, the effectiveness of treatment for atherosclerosis remains completely effective (Wang et al., 2018). Current medical treatment for this condition is statin which is a cholesterol-lowering drug. Patient management also involves changes in lifestyle and supplementation with natural remedies. In many cases, all these can only to prevent complications of atherosclerosis but cannot treat the condition completely. Statin treatment alone showed only a small reduction of coronary disease, and this raises a concern about the balance of the majority of the patients who did not respond to the statin therapy (Wang et al., 2018).

The exosome is an extracellular vesicle of the size 30-150 nm (Chen et al., 2020). It is generated by the inward budding of a mesenchymal cell's membrane that forms an endosome intracellularly where biological substances can be infused into it (Ailawadi et al., 2015). Then, the endosome will form a multivesicular body that will be secreted by the cell as an exosome and can exert its paracrine effect via cell-to-cell communication (Lu et al., 2019). The exosomes can be isolated from various sources, including adipose tissue, bone marrow, human umbilical cord, gingival tissue, dermis, and lung. The cells can also secrete growth factors and immunomodulatory agents (Gomez-Salazar et al., 2020).

The exosomes derived from the mesenchymal stem cells (MSC) can be used to transport various biological substances, including mRNA and miRNA (Wei et al., 2021). Scientists and researchers, particularly in tissue

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engineering and tissue regeneration, are interested in using mesenchymal cells due to their ability to differentiate into different cell types and the simplicity of the exosome's extraction process (Yu et al., 2021). Mesenchymal cell-derived exosomes have demonstrated promising potential as an atherosclerotic treatment (Lin et al., 2020), owing to their capacity to transport biological substances such as microRNA and facilitate cell-to-cell communication (Sun et al., 2021).

Thus, this scoping review was conducted to review the extent of research using exosomes derived from mesenchymal cells in atherosclerosis. Hopefully, this review will provide insight on the fundamental concepts and potential of the exosomes to be used in atherosclerosis treatment.

METHODOLOGY

Research articles were searched using 5 databases subscribed by IIUM library namely Scopus, Cambridge Journal, ScienceDirect, Cochrane library and PubMed. The search was done by using keywords (atherosclerosis OR atherogenesis) AND ('mesenchymal cell' OR 'stem cell') AND (exosome OR exosomes). The Boolean operator "AND" is used to restrict the search, whereas the search was extended by the word "OR". The articles retrieved from the databases were selected and filtered based on inclusion and exclusion criteria. All duplicates were removed, and the remaining articles were screened for eligibility based on the criteria described below.

Selection of Publication for Review

Inclusion Criteria

Publications included for this review were English-language research papers, books, and journals that were published between 2015 and 2022.

Exclusion Criteria

Publications retrieved but excluded were review papers and gray literature such as unpublished papers, patents, posters and infographics. Studies that used other extracellular vesicles instead of exosomes were also excluded as the focus was only for exosome-related experiments. Additionally, research papers that use exosomes as biomarkers were also rejected as our focus was on the mechanism and treatment of atherosclerosis involving MSC exosomes.

Selection Method

The initial selection of publications was based on their titles. Publications included in the review were studies using exosomes generated from mesenchymal cells and studies involving exosomes secreted by other than mesenchymal stem cells were eliminated. Publications involving diseases other than atherosclerosis were also discarded. Selection of publications was done by the first reviewer and verified by the second reviewer.

RESULTS

A summary of the article searched was presented in Figure 1. Article search retrieved a total of 46,059 articles from the chosen databases but only 2,831 were screened because the rest were duplicates and not accessible. Further screening filtered 256 articles. The others were excluded for not complying with the inclusion criteria for this review. One relevant article was removed because we were unable to retrieve the full text of the article from our library. The effort to retrieve the full article from another local academic library was also not successful.

Further screening of the 255 articles based on the abstract removed more irrelevant articles. 102 of them were excluded because they were review articles; 66 articles involved other extracellular vesicles, and the other 78 articles focused on diseases other than atherosclerosis. Only 9 articles were eligible for the full-text review. Therefore, to gain more articles, citation searching methods were used and 3 articles were found eligible to be included for this review. However, the full-text of the two articles was unable to be retrieved. The final number of articles used for this review was 10. Each of the 10 selected full-text articles was read thoroughly, several times by the authors, to capture all relevant information and ensure that nothing important was missed. The dataset for the paper was constructed by extracting findings that were relevant to the aim of this review.

The articles showed that exosomes were extracted from various tissues of humans or mice. Tibia and femurs of mice were the most popular sources of MSC (Table 1). Researchers conducted both in vitro and in vivo studies. In vitro studies showed that the human monocytic line was the most used study model. Whereas in vivo studies mainly used atherosclerosis-prone apolipoprotein E-deficient (ApoE−/−) mice.

Four out of 10 papers investigated apoptosis inhibition in cells that contributed to atherogenesis, while two papers observed cell apoptosis that could reduce atherosclerosis progression. Most of the papers explored the anti-inflammatory property of MSC-exosomes, including their effect on macrophages and inflammatory cell movements.

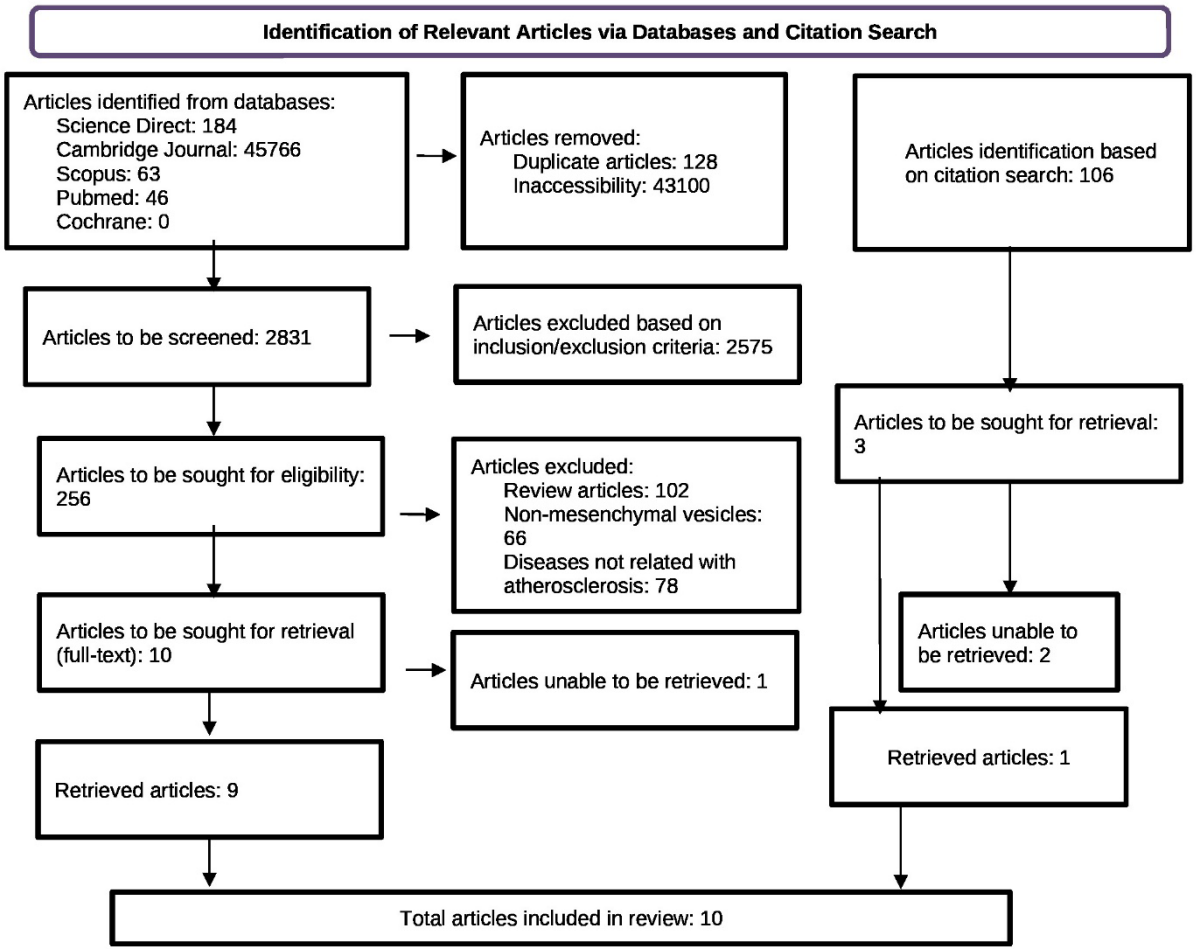

Figure 1: Summary of articles screening for review

DISCUSSION

In vitro models are essential for gathering fundamental data in order to screen for therapeutic effects and understand the mechanism of a particular target. The human monocytic-cell line is the most commonly used in vitro atherosclerotic model by researchers because these cells can develop into macrophage-like cells that are similar to the native monocyte-derived macrophages (Bosshart et al., 2016). Other than that, authors from selected studies used human umbilical vein endothelial cells (HUVEC), aorta endothelial cells from mice, eosinophils from mice's bone marrow, and human smooth muscle cells as in vitro atherosclerotic study models. These cells were either exposed to oxidative stress, such as H2O2, cultivated with ox-LDL, or co-cultured with multiple compounds, such as phorbol myristate acetate to create a suitable atherosclerosis lesion (Xiaohui et al., 2021; Chen et al., 2021; Wenzhi et al., 2021; Feng et al., 2021).

Gathering data from animal models is important because it provides estimations of how a particular target affects an intact organism in a normal or diseased state which could be applicable to humans. Several of the selected studies reviewed used ApoE−/− mice as in vivo models. This mouse model displays poor lipoprotein clearance with subsequent accumulation of cholesterol ester-enriched particles in the blood, which promotes the development of atherosclerotic plaques (Lo Sasso et al., 2016).

As of the date of this review, no research has used exosomes to treat atherosclerosis in human subjects. The data from all of the reviewed papers could be considered preliminary but provided fundamental data before a clinical trial could be considered. Additionally, the papers reviewed showed that the MSC-exosomes were used mainly as carriers for different types of miRNA, proteins and lipids that can interact with different targets at different stages of atherosclerosis progression. It was hypothesized that the delivery of exosomes to the target site could modulate immune cells and reduce inflammation (Brandon et al., 2018).

According to the reviewed articles, only one study used extracted MSCs directly as compounds for atherosclerosis intervention (Xing et al. 2020). The MSC-exosomes were extracted from adipose-derived mesenchymal stem cells (ADSCs) and treated on atherosclerotic endothelial cells.

The treatment reduced the atherosclerotic lesion by inhibiting miR-342-5p expression (Xing et al. 2020). Caspase-3, a protein that promotes apoptotic cell death, was increased in atherosclerosis, and delivery of miR-512-3p using MSC-exosomes could inhibit this protein (Chen et al. 2021).

The remaining reviewed papers revealed that MSC-exosomes primarily function as carriers of microRNA to polarize macrophages. In atherosclerotic plaque, the M1 macrophage phenotype takes up ox-LDL in the tunica intima and forms foam cells. M1 also releases pro-inflammatory cytokines that enhance inflammation. Macrophage has plasticity, allowing it to polarize towards M2 macrophages that promote inflammation termination and eventually reduce atherosclerosis (Bobryshev et al., 2016). M1 macrophages can be reduced by transfection with the miR-let7 family using MSC-exosomes as carriers (Jiangbing et at., 2019). Transfected M1 polarized into M2 and suppressed their infiltration into the atherosclerotic plague.

Table 1: Summary of articles used for the review

Authors	Location of MSC taken	Type of Study Model Used	Summary of findings
Xing et al., (2020)	Human facial adipose tissue	*In vitro*	ADCSs-derived exosome restrained the expression of miR-324-5p in lesion model.
Chen et al., (2020)	Bilateral leg bone of mice	*In vitro*	miR-512-3p shuttled by MSC-derived exosomes protects EC against ox-LDL by targeting Keap1.
Jiangbing et al., (2019)	Tibia and femur of mice	*In vitro, in vivo*	MSC-exosome could improve atherosclerosis by promoting M2 macrophage polarization and suppressed infiltration in the plaque.
Sun et al., (2021)	Human bone marrow	*In vitro, in vivo*	Exosomal-mediated delivery of si-LOC100129516 promoted cholesterol efflux and suppressed intracellular lipid accumulation.
Wenzhi et al., (2021)	Human umbilical cord	*In vitro, in vivo*	Treatment of miR-145-rich exosomes could downregulate JAM-A and reducing atherosclerotic plaque.
Gao et al., (2021)	Human umbilical cord		HuCMSC-Ex-miR-100-5p inhibits cell proliferation and inflammatory response in eosinophil.
Feng et al., (2021)	Thigh bone and shin bone	*In vitro, in vivo*	BMSC-EXO decreases inflammatory reaction, blood lipid, plaque area, MMP-expression, increases α-SMA expression, and inhibits apoptosis.
Jian et al., (2021)	Femur and tibia of mice	*In vivo*	MSC-derived exosomes containing miR-21-a5p promoted macrophage polarization and reduce macrophage infiltration.
Yalong et al., (2021)	Human gingival tissue	*In vitro*	GMSC-Exos reduced the level and expression of inflammatory factors, inhibit lipid accumulation, and promote polarization of pro-inflammatory macrophage.
Yu et al., (2021)	Human adipose tissue	*In vitro, in vivo*	miR-125b-1-3p expressed in hMSCs-Ad exosomes can promote T lymphocyte apoptosis.

Additionally, Jian et al. (2021) demonstrated that increased M2 macrophage polarization occurs through inhibition of transcription factor KLF6. MSC exosomes were employed to deliver miR-21a-5p into M1 macrophages. Furthermore, Gao et al. (2021) demonstrated that miR-100-5p, a microRNA that targets the FZD5 gene to lower the expression of inflammatory cytokines, can be carried by MSC exosomes. Additionally, the reviewed article suggested that miRNA that might boost antioxidant activities in atherogenesis could be delivered via MSC-exosomes. Chen et al.'s study from 2021 demonstrated this, using the delivery of miR-512-3p into atherogenic model-induced ox-LDL-induced endothelial cells to interact with Keap1, resulting in protection against ox-LDL (Tu et al., 2019).

In the early stage of atherosclerosis development, endothelial cell migration results in the loosening of tight junctions (Wenzhi et al., 2021). Transfection of endothelial cells with that microRNA-145 and si-LOC100129516 using MSC-exosome reduced its migration ability [Wenzhi et al., (2021 and Gao et al., (2021)]. Moreover, proliferation of vascular smooth muscle cells (VSMCs) also contributes to the formation of atherosclerotic plaque (Bennett et al., 2016). Feng et al., (2021) found that miR-125b-5p could significantly reverse the proliferation process via inhibition of Map4k4 gene expression that participates in cell proliferation and cell mortality.

Cell apoptosis in atherosclerosis treatment can be disadvantageous or beneficial depending on the type of

cell involved, localizations, and the stage of atherogenesis. For instance, eosinophils in atherosclerotic plaque released a number of cytotoxic and prothrombotic mediators, such as eosinophil peroxidase, which can produce reactive oxygen species (ROS) and promote atherosclerosis (Gao et al., 2021. MSC-exosomes that carry miR-100-5p were shown to reduce atherosclerotic plaque formation by promoting apoptosis (Gao et al., 2021).

MSC-exosome experimentation in animal models is also important because the animal models can provide reliable preclinical data on a particular intervention in atherosclerosis. The reviewed papers indicate that ApoE-/- mice were the subjects of all in vivo studies. Even when fed a normal diet, ApoE-/- mice severely impair their ability to clear plasma lipoproteins, leading to elevated blood cholesterol levels (Zhang et al., 2021). According to the reviewed papers, researchers also used exosomes derived from mesenchymal cells as a carrier for microRNA in an animal model, leading to a reduction in the animal's lipid profile [Yu et al. (2020), Sun et al. (2021)].

MSC-exosomes can promote angiogenesis, gene alteration, and have a vital role in cell-to-cell communication (Lu et al., 2019; Wei et al., 2021; Yang et al., 2021). Moreover, Thomas et al., (2021) stated that exosomes derived from MSCs have a role in promoting the apoptosis rate of cells, attenuating blood lipid levels, and reducing atherosclerosis in an in vivo model. The MSC-exosome may bring a light in the future treatment because it is found to have less tumorigenicity which is one of the problems faced in MSC transplantation treatment (Lu et al., 2019; Neri, 2019). Neri, (2019) added that gene alteration and modification of the expression often become a topic of discussion in MSC transplantation treatment. However, Harrell et al., (2019) stated that exosomes derived from mesenchymal cells can avoid the potential of unwanted immunogenicity response and possible tumorigenicity because the structure of it has a similar biological composition with the human cell.

In conclusion, the reviewed papers showed that MSC exosomes were mainly used as carriers for microRNA. Thus, treatment of atherosclerosis using exosome technology derived from mesenchymal cells has yet to reach clinical trial. Nevertheless, the ability of the exosome as a nanocarrier may open many gates for future research in finding new technologies for treatment of various diseases. MicroRNA carried by exosomes was shown to inhibit atherosclerosis formation and progression. However, current knowledge of this technology is still lacking in many parts for instance, the best method to extract higher quality exosomes, the uncertainty of how the injected exosome will crosstalk with the local immune cell in endothelial cells, and the survival rate of the exosome after implantation (Lin et al., 2020). Moreover, as the progression of atherosclerosis involves numerous processes, the research area can be wide-ranging and open to a lot of options.

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