Journal of Exercise Sciences
& Physical Activity Reviews

ORIGINAL ARTICLE

Predicting mental impairment in sarcopenic elderly women using machine learning and association rules

Fatma Hilal Yagin[1*] | Matheus Santos de Sousa Fernandes[2]

[1]Biostatistics and Medical Informatics, Faculty of Medicine, Inonu University, Malatya, Türkiye
[2]Keizo Asami Institute, Federal University of Pernambuco, 50670-420 Recife, Pernambuco, Brazil

ABSTRACT

Sarcopenia, a prevalent condition in the elderly characterized by muscle mass and function deterioration, is associated with increased risks of falls, functional decline, frailty, and mortality. This study investigates the link between sarcopenia and cognitive impairment in elderly women and develops a machine-learning prediction model based on association rules to forecast mental status. A total of 67 community-dwelling women aged 60 and above participated in this cross-sectional study. Cognitive function was assessed using the Mini-Mental State Examination (MMSE), and physical activity levels were measured through self-reported activity logs and the six-minute walk test (6MWT). Regularized Class Association Rules (RCAR) were employed to create a prediction model. Results indicated that weekly walking, increased moderate physical activity, and reduced sitting time were significantly associated with lower severity of mental impairment. Specifically, women with a higher Skeletal Muscle Index (SMI) and consistent moderate physical activity demonstrated better cognitive performance. The RCAR model achieved high accuracy (94%), balanced accuracy (93.9%), sensitivity (92.9%), and specificity (94.9%) in predicting cognitive impairment. These findings emphasize the importance of physical activity in mitigating cognitive decline in sarcopenic elderly women and highlight the potential of machine-learning approaches in developing predictive models for clinical applications. Future research targeting sarcopenia could play a crucial role in improving both physical and mental health in the aging population.

Keywords: Sarcopenia, cognitive impairment, elderly women, physical activity, machine-learning

***Corresponding:** Fatma Hilal Yagin; hilal.yagin@inonu.edu.tr
Journal home page: www.e-jespar.com
Academic Editor: Dr. Mehmet Gülü
https://doi.org/10.5281/zenodo.12601047

ARTICLE HISTORY
Received: 20 May 2024
Accepted: 26 May 2024
Published: 01 July 2024

INTRODUCTION

Sarcopenia is a prevalent disorder in the elderly that is characterized by increasing muscle mass and function deterioration. It is linked to serious problems such as falls, functional decline, frailty, and death (Cruz-Jentoft et al., 2019). Sarcopenia prevalence ranges from 9.9% to 40.4%, depending on the criteria (Kaeberlein, Rabinovitch, & Martin, 2015). There is currently no agreement on determining the cut-off points, making sarcopenia diagnosis difficult. Indeed, merely seven days of decubitus resulted in muscle mass loss, while a longer time, 90-120 days, lost 30% of muscle mass (Alkner & Tesch, 2004; Shackelford et al., 2004).

The health implications of sarcopenia extend beyond physical decline. According to recent research, increasing physical activity levels might prevent roughly 3% of all dementia cases (Liang et al., 2020; Livingstone, 2000). Simultaneously, growing evidence supports the relevance of physical activity and exercise in preventing or slowing the degenerative process and dementia-related issues (Vancampfort, Solmi, Firth, Vandenbulcke, & Stubbs, 2020).

It is widely recognized in the literature that sarcopenia raises the risk of cognitive deterioration (Cabett Cipolli, Sanches Yassuda, & Aprahamian, 2019). Research of 555 individuals, all of whom were 85 years old at the start, found that hand grip strength was related to processing speed and memory performance (Taekema et al., 2012). Skeletal muscle atrophy and mental impairment are both caused by aging. Furthermore, because lifestyle risk factors, including physical inactivity, are shared by both illnesses, their possible function in the muscle-brain link further enhances their well-being. The bidirectional relationship between muscle and brain health underscores the importance of addressing sarcopenia not only for physical well-being but also for cognitive health.

Given the complexity and multi-dimensional aspects of sarcopenia and its impact on the elderly, advanced analytical methods are required to better understand and predict these outcomes. This study aims to develop a machine learning prediction model based on association rules to predict mental status in sarcopenic elderly women. By leveraging data-driven approaches, we hope to identify patterns and risk factors that could inform interventions to improve both physical and mental health in this vulnerable population.

METHODS

Participant and Data

69 women over the age of 60 agreed to participate in the study, and two women were excluded because the Mini Mental State Examination (MMSE) score was ≤ 12. The inclusion criteria for the study were that participants had to be able to walk independently without any mobility limitations or muscle weakness that would affect their ability to perform the tests. They also could not have any unstable cardiovascular conditions, acute infections, tumors, back pain, knee or hip prostheses, or any other limitations that would

prevent them from performing the tests. The exclusion criteria for the study were that participants could not have any discontinuity in the study, be diagnosed with cancer, have uncontrolled chronic diseases, stroke sequelae, weight loss greater than 3 kg in the last three months, or dementia. These criteria were put in place to ensure that the participants were physically and cognitively capable of performing the tests and that any changes observed in the study could be attributed to the intervention being tested rather than other factors that could affect the results. The data used in this study are data from research published as open access (Gonalves Marini et al., 2023).

Mobility

The mobility of participants was assessed using the six-minute walk test (6MWT), which was conducted in a corridor that was 30 meters long. The path was marked with cones placed every three meters to help the researcher precisely identify the distance covered by the participant. During the 6MWT, participants were instructed to walk as far as they could in six minutes, at a pace that was comfortable for them. They were encouraged to walk as fast as they could, but were also allowed to slow down or take a break and resume walking whenever they needed to. However, the time was not paused during breaks or pauses in walking. The 6MWT is a commonly used test for assessing functional capacity and mobility in clinical and research settings. It is a reliable and valid measure of walking endurance and has been shown to be responsive to changes in functional capacity over time. By using the 6MWT to assess mobility, the researchers were able to objectively measure the participants' ability to walk independently (Gonalves Marini et al., 2023).

Cognition assessment

The MMSE is a commonly used tool for assessing cognitive function and screening for dementia in clinical and research settings. It consists of a series of questions and tasks that evaluate various aspects of cognitive function, including orientation, attention, memory, language, and visuospatial ability. The test is typically administered face to face with a trained researcher or clinician in a quiet room. In this particular study, the short version of the MMSE was used to assess the participants' cognitive status and ensure that they were able to understand the other tests administered as part of the study. Participants with an MMSE score of 12 or lower were considered to have dementia and were excluded from the study (Gonalves Marini et al., 2023).

Statistical Approach

The conformity of quantitative variables to univariate normal distribution was examined with visual (histogram and probability graphs) and analytical (Kolmogorov-Smirnov test) methods. The assumption of homogeneity of variances was examined with Levene test. Since quantitative variables showed normal distribution, they were expressed as mean and standard deviation. Independent two-sample t-test was used for group comparison and for comparisons with significant p value, Cohen d effect size was calculated. Pearson correlation analysis was performed to examine the correlations between individual variables for mental state levels. In all results, $p < 0.05$ was considered statistically significant. Statistical analyses were performed using Python 3.9 software and SPSS 28.0 (IBM Corp., Armonk, NY, USA) package program.

Machine Learning Approach

In the study, Regularized Class Association Rules (RCAR), an Associative classification method, was used to predict the mental status of patients with Sarcopenia based on association rules according to anthropometric criteria and physical activity status. Since the RCAR algorithm can work with categorical data, quantitative data were optimally categorized with the Ameva discretization method. The results are presented with association rules, classification performance metrics and network graph of rules. In order to evaluate the classification performance of RCAR, sensitivity¸ specificity, accuracy, balanced accuracy, negative predictive value, positive predictive value and F1-score metrics were used. The machine learning approach used in the study is explained in detail in the sub-titles.

Data Discretization

Discretization is a commonly used data preprocessing technique in many knowledge discoveries, machine learning, and data mining tasks. It involves converting continuous data into discrete form, which is more suitable for use with many algorithms and models. The process of discretization involves dividing a range of continuous values into a set of discrete intervals or categories, and then assigning categorical values to these intervals. This allows quantitative data to be transformed into qualitative data, which can be used more effectively by many data mining algorithms. Discretization is particularly useful for handling data with a large number of continuous attributes, as it can simplify the data and improve the performance of many knowledge discovery and data mining approaches. It can also help to reduce the noise and variability in the data, making it easier to identify meaningful patterns and relationships. Overall, discretization is an important technique for preprocessing data in many knowledge discovery, machine learning, and data mining applications, and can play a critical role in improving the accuracy and performance of these approaches (Malina, Bouchard, & Bar-Or, 2004).

The Ameva discretization method is a data preprocessing technique that aims to generate a minimal number of discrete intervals from continuous data, without requiring the user to specify the number of intervals. The approach is based on maximizing a contingency coefficient using Chi-square statistics. The contingency coefficient is a measure of association between two variables, and is used to evaluate the strength of the relationship between the continuous attribute and the class variable. By maximizing this coefficient, the Ameva aims to identify the most relevant intervals that capture the underlying patterns in the data. Unlike other discretization approaches, which require the user to specify the number of intervals or use predefined criteria, the Ameva does not rely on any such input. Instead, it uses an iterative procedure to identify the optimal number of intervals, based on the strength of the association between the continuous attribute and the class variable.

Overall, the Ameva is a useful approach for discretizing continuous data, particularly in situations where the number of intervals is not known in advance or may vary across different datasets. By maximizing the contingency coefficient and identifying the most relevant intervals, the Ameva can improve the accuracy and performance of many data mining and machine learning algorithms (Gonzalez-Abril, Cuberos, Velasco, & Ortega, 2009; Yılmaz & Tekin, 2022).

Associative Classification Method

Association rules are a powerful unsupervised data mining method that can help discover interesting relationships and patterns in large datasets. These rules use IF-THEN expressions to show relationships between data records, and they are measured by support and trust values. Association rules can be used in a wide range of fields, including marketing, healthcare, and finance, to uncover important insights that might be difficult to discover otherwise. By analyzing past data, association rules can also help support future studies by identifying patterns and relationships that may be useful for predicting future events or behaviors (Agrawal, Imieliński, & Swami, 1993; Kumar & Wahidabanu, 2009).
Associative classification is a supervised learning model that uses association rules to classify data. In this model, the association rules are derived from the training data using “IF-THEN" clauses called precursor-successor rules. The right side or the successor of the association rules in associative classification only consists of the categories of the response or dependent variable, which is the class label that we are trying to predict. These association rules are then used to classify new, unlabeled data. The classification is done by applying the relevant association rules to the test data and assigning the class label that corresponds to the most relevant rule. Associative classification is a powerful approach to classification, especially when the data contains a large number of categorical attributes and the class labels are imbalanced (Singh, Kamra, & Singh, 2016; Thabtah, 2007).

Regularized Class Association Rules (RCAR)

RCAR is an algorithm that uses association rules to create a classification model for categorical datasets. The algorithm mines a set of rules based on predetermined thresholds of minimum support and trust criteria. The rules are then used to predict the conditional probability of the class variable using Lasso's regularized logistic regression analysis. The rules kept in the model include meta-rules, which are one-way associations. These meta-rules are used in Lasso regularization to select the most important rules and organize them into a pruned rule space. The RCAR algorithm uses a method similar to Apriori (Hegland, 2007) to reveal the closed association rules, and the rule pruning problem is solved by arranging the Lasso. An optional pruning step can be performed based on an in-depth analysis of established rules and meta-rules. This step can further improve the model's accuracy and reduce its complexity. Overall, RCAR is a useful algorithm for creating classification models for categorical datasets using association rules. By combining rule mining and logistic regression analysis, RCAR can create models that are accurate and interpretable, making it useful in various applications (Azmi, Runger, & Berrado, 2019; Eddermoug, Mansour, Sadik, Sabir, & Azmi, 2021).

Performance evaluation metrics

Performance evaluation metrics are used to evaluate the performance of different classification models. In the study used performance metrics include:

Sensitivity: The proportion of true positives (correctly classified positive instances) among all actual positive instances.

Specificity: The proportion of true negatives (correctly classified negative instances) among all actual negative instances.

Accuracy: The proportion of correct classifications (both true positives and true negatives) among all instances.

Balanced accuracy: The average of sensitivity and specificity, which takes into account the imbalance between positive and negative instances in the data.

Negative predictive value: The proportion of true negatives among all instances predicted as negative.

Positive predictive value: The proportion of true positives among all instances predicted as positive.

F1-score: The harmonic mean of precision and recall, which balances both metrics and is especially useful when the class distribution is imbalanced (Tharwat, 2021).

These metrics provide valuable insights into the performance of a classification model and can help identify areas for improvement. Depending on the specific problem and application, different metrics may be more or less important, so it is important to carefully consider the appropriate metrics for a given task.

RESULTS

The participants consisted of 67 community-dwelling older women (age: 69.8 ± 5.9 years). Twenty-eight (41.8%) of the sample had severe mental disorders. Descriptive data are given in Table 1. Age, height, weight and BMI results did not differ between women with severe mental disorders and those with moderate mental disorders ($p > 0.05$). Women with moderate mental disorders walked significantly more days ($p < 0.05$; ES: 0.67; moderate). However, there were no significant differences between women with severe mental disorders and women with moderate mental disorders in terms of sitting time, SMI, walking duration, moderate/vigorous PA days and duration ($p > 0.05$).

Variable*	Mental State		p-value	ES
	SCI	MCI		
Age (years)	71.179±7.175	68.769±4.809	0.13	-
Height (cm)	154.561±5.646	157.269±6.113	0.069	-
Weight (kg)	65.188±10.953	67.578±12.035	0.408	-
BMI (kg/m²)	27.349±4.899	27.26±4.15	0.937	-
walk days	3.571±2.201	5.051±2.212	0.009**	0.67 (moderate)
walk minutes	58.214±46.032	68.462±97.273	0.607	-
Moderate-PA days	4.714±2.123	5.41±2.112	0.189	-
Moderate-PA minutes	159.107±115.406	193.846±133.98	0.272	-
Vigorous-PA days	0.5±0.962	0.615±0.935	0.624	-
Vigorous-PA minutes	11.786±22.493	20.205±34.344	0.261	-
Sitting time (min/week)	1253.929±520.736	1466.923±675.458	0.167	-
6MWD	367.218±93.189	446.963±76.669	<0.001**	0.95 (large)
SMI	6.304±1.037	6.282±0.914	0.925	-

*: Data summarized with mean and standard deviation; **: statistical significance; BMI: body mass index; SMI=skeletal muscle index; 6MWD=six-minute walk distance; PA=physical activity; min/week= minutes per week.

Table 1. Results of univariate statistical analysis in mental status groups

The correlation analysis results depicted in Figure 1 highlight the relationships between various physical and demographic variables in individuals with severe mental disorders. Height shows a strong positive correlation with ASMM-H, suggesting that taller individuals tend to have greater muscle mass. Weight and BMI exhibit strong negative correlations with the 6MWD, implying that higher body mass is associated with reduced physical fitness or mobility. These findings underscore the importance of managing weight and improving physical activity to enhance mobility and overall health in this population (Figure 1).

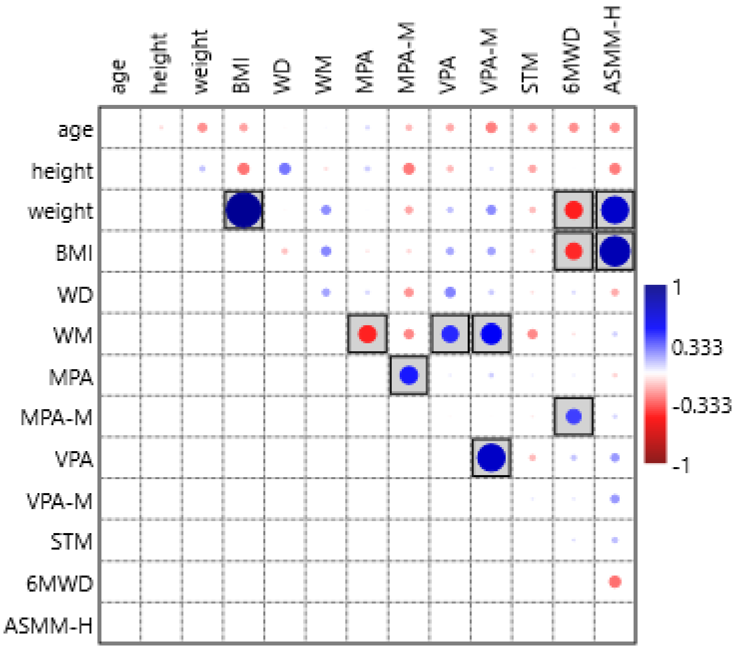

Figure 1. Results of correlation analysis in those with severe mental disorders

Table 2 presents the association rule results for the RCAR method used to estimate the severity of mental disorders in elderly women. Some association rules in Table 2 are explained below:

Rule 1. Elderly women with a BMI between 20.2 and 32.3 and SMI greater than 5.5 have an 88.2% probability of having moderate cognitive impairment (support: 0.224; confidence: 0.882), thus having a lower probability of having severe cognitive impairment.

Rule 3. Elderly women who do 50 to 155 minutes of moderate physical activity weekly and have a 6MWD score lower than 400 have an 85% probability of having severe cognitive impairment (support: 0.254; confidence: 0.85).

Rule 5. Elderly women with a BMI between 20.2 and 32.3 who spend less than 375 minutes per week sitting have a 100% probability of having moderate cognitive impairment (support: 0.239; confidence: 1). Based on this, reducing the time spent sitting may reduce the severity of cognitive impairment.

According to the results of the rules obtained with the RCAR method, weekly walking (days), the amount of moderate physical activity (minutes) and the time spent sitting (minutes) were associated with the severity of cognitive activity. The results showed that walking 7 days a week, increasing moderate physical activity and reducing the time spent sitting may reduce the severity of cognitive impairment. A 6MWD result of less than 400 was also associated with severe cognitive impairment and was determined to increase the severity of cognitive impairment. Moreover, it was determined that SMI greater than 5.5 decreased the severity of cognitive impairment. Based on this, it can be said that sarcopenia also affects severe cognitive impairment.

Rule number	Input	Output	Support	Confidence
1	{BMI =[20.2,32.3), ASMM・height^{-2} =[5.5,6.5)}	MCI	0.224	0.882
2	{walk days =7, sitting time minutes in 7 days =[0, 375)}	MCI	0.239	1
3	{ moderatePA minutes =[50,155), 6MWD =[174,400)}	SCI	0.254	0.85
4	{ age =[60,79.5), BMI =[20.2,32.3), ASMM・height^{-2} =[5.5,6.5)}	MCI	0.224	0.882

5	{ BMI =[20.2,32.3), walk days =7, sitting time minutes in 7 days =[0, 375)}	MCI	0.239	1
6	{ moderatePA minutes =[50,155), vigorousPA minutes =[0,75), 6MWD =[174,400)}	SCI	0.254	0.85
7	{ weight =[46.4,73.9), moderatePA minutes =[50,155), vigorousPA minutes =[0,75)}	SCI	0.209	0.737
8	{ height =[145,156), vigorousPA minutes =[0,75), sitting time minutes in 7 days =[375, 2280)}	SCI	0.269	0.6
9	{ vigorousPA minutes =[0,75), sitting time minutes in 7 days =[375, 2280), 6MWD =[174,400)}	SCI	0.313	0.724
10	{ age =[60,79.5), BMI =[20.2,32.3), moderatePA minutes =[155,600)}	MCI	0.343	0.821
11	{ age =[60,79.5),weight =[46.4,73.9), BMI =[20.2,32.3), 6MWD =[400,613)}	MCI	0.313	0.913
12	{ age =[60,79.5),weight =[46.4,73.9), moderatePA days=7, moderatePA minutes =[155,600)}	MCI	0.209	0.875

BMI: body mass index; DXA: dual-energy X-ray absorptiometry; ASMM: appendicular skeletal muscle mass; PA: physical activity; 6MWD: six minutes walking distance; MCI: Mild cognitive impairment; SCI: Severe cognitive impairment.

Table 2. Results regarding association rules

The RCAR model demonstrates strong performance in predicting the severity of mental disorders in older women, as indicated by its high accuracy of 0.940. This means that 94% of its predictions are correct. It maintains a balanced accuracy of 0.939, ensuring it performs well on both positive and negative cases, which is crucial for datasets that might not be perfectly balanced. The model's sensitivity of 0.929 shows it accurately identifies 92.9% of true positive cases, while its specificity of 0.949 indicates it correctly identifies 94.9% of true negative cases. Furthermore, the positive predictive value of 0.929 means 92.9% of positive predictions are correct, and the negative predictive value of 0.949 means 94.9% of negative predictions are accurate. Finally, the F1-score of 0.929 highlights the model's ability to balance precision and recall effectively, confirming its reliability in identifying both positive and negative cases accurately (Table 3).

Metric	Value
Accuracy	0.940
Balanced accuracy	0.939
Sensitivity	0.929
Specificity	0.949
Positive predictive value	0.929
Negative predictive value	0.949
F1-score	0.929

Table 3. Performance measures of the RCAR model's performance in predicting mental disorder severity in older women

DISCUSSION

Sarcopenia, the rapid loss of muscle mass and strength, is significant since it indicates a number of unfavorable consequences. It is well-accepted and empirically confirmed that sarcopenia plays a part in the processes that lead to physical deterioration; however, its relationship to cognitive dysfunction is less evident. Despite the widespread belief that motor neurone dysfunction can result in losses of muscle mass and strength, it is not possible to rule out a reverse association through a decline in participation in physical activity or a common underlying process. This suggests a complex interplay between physical and cognitive decline, in which sarcopenia may play a significant role (MacDonald, DeCarlo, & Dixon, 2011; Sternäng et al., 2015). In this study, we developed a predictive model based on association rules to estimate the level of cognitive impairment in older women with sarcopenia.

The participants consisted of 67 community-dwelling older women (age: 69.8 ± 5.9 years). Twenty-eight (41.8%) of the sample had severe mental disorders. Age, height, weight and BMI results did not differ between women with severe mental disorders and those with moderate mental disorders ($p > 0.05$). Women with moderate mental disorders walked significantly more days ($p < 0.05$; ES: 0.67; moderate). However, there were no significant differences between women with severe mental disorders and women with moderate mental disorders in terms of Sitting time, SMI (SMI=skeletal muscle index), walking time, moderate/vigorous PA days and duration ($p > 0.05$). According to the results of the rules obtained with the RCAR method, weekly walking (days), amount of moderate physical activity (minutes) and time spent sitting (minutes) were associated with cognitive activity intensity.

SMI higher than 5.5 was found to reduce the severity of cognitive impairment. These findings support the studies in the literature. As a matter of fact recent systematic review and meta-analysis found that the relationship between sarcopenia and cognitive impairment was unaffected by the research population, sarcopenia definition, or degree of cognitive impairment (odds ratio 2.2, 95% CI 1.2-4.2) (Peng, Chen, Wu, Chang, & Kao, 2020). Significant reduction in muscle loss with age is related with poorer cognitive impairment, which offered new evidence for a robust connection that requires additional investigation into molecular insights (Hu, Peng, Ren, Wang, & Wang, 2022). Sarcopenia patients were six times more likely than controls to have combined cognitive/physical impairment, with a fully adjusted model revealing a three-fold elevated odds ratio (Tolea & Galvin, 2015).

In conclusion the results showed that walking 7 days a week, increasing moderate physical activity, and decreasing the time spent sitting can reduce the severity of cognitive impairment. A 6MWD result of less than 400 was also associated with severe cognitive impairment and was determined to increase the severity of cognitive impairment. Furthermore, it was determined that an SMI greater than 5.5 decreased the severity of cognitive impairment. Based on this, it can be said that sarcopenia also affects severe cognitive impairment. Interventions aimed at preventing sarcopenia and increasing muscular strength may assist to alleviate the burden of cognitive and physical deficits in community-dwelling seniors.

CONCLUSIONS

This study investigated the relationship between sarcopenia and cognitive impairment in a cohort of community-dwelling older women, employing a machine-learning approach to develop a predictive model for mental disorder severity. The findings reveal several important associations and insights:

Physical Activity and Cognitive Health: Increased frequency of weekly walking and higher levels of moderate physical activity were associated with reduced severity of cognitive impairment, highlighting the beneficial effects of physical activity on cognitive function in elderly women.

Sarcopenia and Muscle Health: Women with a higher Skeletal Muscle Index (SMI) tended to exhibit milder cognitive impairment, suggesting that preserving muscle mass could play a protective role against cognitive decline in aging.

RCAR Model Performance: The Regularized Class Association Rules (RCAR) model demonstrated robust predictive performance with an accuracy of 94%, balanced accuracy of 93.9%, and high sensitivity (92.9%) and specificity (94.9%). These metrics underscore the model's efficacy in identifying and predicting the severity of cognitive impairment based on demographic and physical activity data.

Clinical Implications: The study's findings support the integration of physical activity interventions, particularly walking and moderate exercise, into clinical practice to potentially mitigate cognitive decline in elderly women at risk of sarcopenia. The RCAR model offers a valuable tool for healthcare professionals to identify individuals at higher risk of cognitive impairment early, enabling targeted interventions and personalized care strategies.

In conclusion, this research underscores the critical role of physical activity and muscle health in cognitive aging among elderly women. Future studies should further explore longitudinal impacts and intervention strategies aimed at optimizing both physical and cognitive health in aging populations

Author Contributions

Conceptualization, F.H.Y. methodology, F.H.Y, M.S.S.F.; formal analysis, M.S.S.F.; investigation, M.S.S.F.; data curation, F.Y.H.; writing–original draft preparation, F.H.Y, M.S.S.F.; writing–review and editing, F.H.Y, M.S.S.F.

Informed Consent Statement:

The research was conducted in line with the Declaration of Helsinki.

Acknowledgments:

We would like to thank all participants who took part in the research.

Funding:

This research was not funded by any institution or organization.

Conflicts of Interest:

The authors declare that no conflicts interest.

REFERENCES

Agrawal, R., Imieliński, T., & Swami, A. (1993). *Mining association rules between sets of items in large databases.* Paper presented at the Proceedings of the 1993 ACM SIGMOD international conference on Management of data.

Alkner, B. A., & Tesch, P. A. (2004). Knee extensor and plantar flexor muscle size and function following 90 days of bed rest with or without resistance exercise. *Eur J Appl Physiol, 93*(3), 294-305. doi: 10.1007/s00421-004-1172-8

Azmi, M., Runger, G. C., & Berrado, A. (2019). Interpretable regularized class association rules algorithm for classification in a categorical data space. *Information Sciences, 483*, 313-331.

Cabett Cipolli, G., Sanches Yassuda, M., & Aprahamian, I. (2019). Sarcopenia Is Associated with Cognitive Impairment in Older Adults: A Systematic Review and Meta-Analysis. *J Nutr Health Aging, 23*(6), 525-531. doi: 10.1007/s12603-019-1188-8

Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., . . . Zamboni, M. (2019). Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing, 48*(1), 16-31. doi: 10.1093/ageing/afy169

Eddermoug, N., Mansour, A., Sadik, M., Sabir, E., & Azmi, M. (2021). *KLM-based profiling and preventing security attacks for cloud computing: A comparative study.* Paper presented at the 2021 28th International Conference on Telecommunications (ICT).

Gonalves Marini, J. A., Abdalla, P. P., Bohn, L., Mota, J., Duncan, M., Dos Santos, A. P., & Lopes Machado, D. R. (2023). Moderate physical activity reduces the odds of Sarcopenia in community-dwelling older women: a cross-sectional study. *Current Aging Science, 16*(3), 219-226.

Gonzalez-Abril, L., Cuberos, F. J., Velasco, F., & Ortega, J. A. (2009). Ameva: An autonomous discretization algorithm. *Expert Systems with Applications, 36*(3), 5327-5332.

Hegland, M. (2007). The apriori algorithm–a tutorial. *Mathematics and computation in imaging science and information processing*, 209-262.

Hu, Y., Peng, W., Ren, R., Wang, Y., & Wang, G. (2022). Sarcopenia and mild cognitive impairment among elderly adults: The first longitudinal evidence from CHARLS. *J Cachexia Sarcopenia Muscle, 13*(6), 2944-2952. doi: 10.1002/jcsm.13081

Kaeberlein, M., Rabinovitch, P. S., & Martin, G. M. (2015). Healthy aging: The ultimate preventative medicine. *Science, 350*(6265), 1191-1193. doi: 10.1126/science.aad3267

Kumar, A. S., & Wahidabanu, R. (2009). Data Mining Association Rules for Making Knowledgeable Decisions *Data Mining Applications for Empowering Knowledge Societies* (pp. 43-53): IGI Global.

Liang, J. H., Lu, L., Li, J. Y., Qu, X. Y., Li, J., Qian, S., . . . Xu, Y. (2020). Contributions of Modifiable Risk Factors to Dementia Incidence: A Bayesian Network Analysis. *J Am Med Dir Assoc, 21*(11), 1592-1599.e1513. doi: 10.1016/j.jamda.2020.04.006

Livingstone, B. (2000). Epidemiology of childhood obesity in Europe. *European journal of pediatrics, 159*(1), S14-S34.

MacDonald, S. W., DeCarlo, C. A., & Dixon, R. A. (2011). Linking biological and cognitive aging: toward improving characterizations of developmental time. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 66*(suppl_1), i59-i70.

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity*. Human kinetics.

Peng, T. C., Chen, W. L., Wu, L. W., Chang, Y. W., & Kao, T. W. (2020). Sarcopenia and cognitive impairment: A systematic review and meta-analysis. *Clin Nutr, 39*(9), 2695-2701. doi: 10.1016/j.clnu.2019.12.014

Shackelford, L. C., LeBlanc, A. D., Driscoll, T. B., Evans, H. J., Rianon, N. J., Smith, S. M., . . . Lai, D. (2004). Resistance exercise as a countermeasure to disuse-induced bone loss. *J Appl Physiol (1985), 97*(1), 119-129. doi: 10.1152/japplphysiol.00741.2003

Singh, J., Kamra, A., & Singh, H. (2016). *Prediction of heart diseases using associative classification.* Paper presented at the 2016 5th International conference on wireless networks and embedded systems (WECON).

Sternäng, O., Reynolds, C. A., Finkel, D., Ernsth-Bravell, M., Pedersen, N. L., & Dahl Aslan, A. K. (2015). Factors associated with grip strength decline in older adults. *Age and ageing, 44*(2), 269-274.

Taekema, D. G., Ling, C. H., Kurrle, S. E., Cameron, I. D., Meskers, C. G., Blauw, G. J., . . . Maier, A. B. (2012). Temporal relationship between handgrip strength and cognitive performance in oldest old people. *Age Ageing, 41*(4), 506-512. doi: 10.1093/ageing/afs013

Thabtah, F. (2007). A review of associative classification mining. *The Knowledge Engineering Review, 22*(1), 37-65.

Tharwat, A. (2021). Classification assessment methods. *Applied computing and informatics, 17*(1), 168-192.

Tolea, M. I., & Galvin, J. E. (2015). Sarcopenia and impairment in cognitive and physical performance. *Clinical interventions in aging, 10*, 663-671. doi: 10.2147/cia.S76275

Vancampfort, D., Solmi, M., Firth, J., Vandenbulcke, M., & Stubbs, B. (2020). The Impact of Pharmacologic and Nonpharmacologic Interventions to Improve Physical Health Outcomes in People With Dementia: A Meta-Review of Meta-Analyses of Randomized Controlled Trials. *J Am Med Dir Assoc, 21*(10), 1410-1414.e1412. doi: 10.1016/j.jamda.2020.01.010

Yılmaz, K., & Tekin, R. (2022). Comparison of discretization methods for classifier decision trees and decision rules on medical data sets. *Avrupa Bilim ve Teknoloji Dergisi*(35), 275-281.