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Application Notes

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Recreating Fall Risk Appraisal matrix using R to support fall prevention programs

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Abstract

Objective: This study aimed to optimize Fall Risk Appraisal (FRA) graphing for use in intervention programs tailored toward reducing the fall risk of older adults by using computing graphic functions in the R language.

Materials and Methods: We utilized RStudio, a free development environment for the R language, as well as the functions within the "ggplot2" and "grid" packages, to develop a code that would recreate the FRA matrix for use in data visualization and analysis, as well as feedback for older adults.

Results: The developed code successfully recreates the FRA matrix in R and allows researchers and clinicians to graph participant data onto the matrix itself.

Discussion: The use of an R code allows for a streamlined approach to manipulating the FRA matrix for use in data visualization and feedback for older adults, which improves upon the traditional paper-pencil method that has been previously used.

Conclusions: The code presented in this study recreates the FRA matrix instrument in the R language and gives researchers the ability to instantaneously add, remove, or change different aspects of the instrument to improve its readability for researchers and older adults.

Lay Summary

Intervention programs utilize visual representations of data to assist in providing feedback to study participants, as well as determining the performance of the participants throughout the course of a program. One instrument, the Fall Risk Appraisal (FRA) matrix, is a graphical grid that has been previously developed to categorize older adults based on their self-perceived fall risk and physical balance. For the matrix, self-perceived fall risk is determined using the Short Falls Efficacy Scale International (Short FES-I) questionnaire, and physical balance is determined using the BTrackS Balance System (BBS). The FRA matrix was originally designed using Microsoft Paint, which lacks the ability to accurately graph coordinate points on the matrix itself. The ability to accurately graph data points (Short FES-I and BBS intersections for an individual) on the FRA matrix allows for easier visualization of data for researchers, as well as older adults. Here, we present a code in R that accurately recreates the FRA matrix and enables a researcher to graph individual data points, as well as add supplementary information, directly onto and around the graph. The use of this code allows for a more streamlined approach to visualizing data for fall risk assessments in research and clinical practice.

Key words: computer software; fear of falling; balance; older adults; FRA.

Background and significance

As of 2023, falls were the leading cause of injury for older adults, as found by the Centers for Disease Control and Prevention (CDC).[1] To reduce the occurrence of falls, many intervention programs have been developed and implemented to improve the fall risk of older adults.[2,3] Various instruments are used in such intervention programs to assist in assessing the fall risk of older adults, determining their level of physical function, and visualizing their progress throughout the duration of the program.[4,5] One instrument, the Fall Risk Appraisal (FRA) matrix, is a graphical grid that was developed to adequately visualize maladaptive FRA among older adults, a condition resulting from a discrepancy between self-perceived fall risk and physical fall risk.[6,7] The FRA matrix categorizes levels of perceived fall risk (fear of falling; FOF) and physical balance into 4 quadrants: (1) rational FRA (low FOF and normal balance), (2) incongruent FRA (low FOF and poor balance), (3) irrational FRA (high FOF despite and balance), and (4) congruent FRA (high FOF and poor balance). For this graphical grid, physical balance is graphed on the horizontal axis and measured using the BTrackS Balance System (BBS). The BBS calculates an individual's fall risk based on the average amount of postural sway (in cm) that an individual exhibits during a standing non-visual static balance test. The BBS categorizes individuals into 3 fall risk categories: low fall risk (postural sway < 33 cm), moderate fall risk (33 cm $\leq$ postural sway < 41 cm), and high fall risk (postural sway ≥ 41 cm).[8] The range of

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values for the horizontal axis of the FRA matrix was set from 0 to 80 cm at intervals of 5 for clearer visualization of data. For the vertical axis, the level of FOF is graphed and measured using the Short Falls Efficacy Scale International (Short FES-I), a 7-item self-report questionnaire that is used to measure an individual's FOF by assessing levels of concern in certain situations.[9] The questions on the Short FES-I utilize a 4-point Likert scale and are based on the level of concern that an individual has about the possibility of falling in certain situations ranging from 1 ("no concern"/"none") to 4 ("very concerned"/"a lot"). The score range for the Short FES-I is from 7 to 28, but the vertical axis range for the FRA matrix was set from 0 to 30 with intervals of 5 to stay consistent with the values and intervals along the horizontal axis. The intersection between an individual's BBS score and a Short FES-I score constitutes a single data point within the FRA matrix, indicating their placement within one of the 4 quadrants and the relationship between their perceived (Short FES-I) and physical (BBS) fall risk.

Encompassing common and clinically practical fall risk assessments, the FRA matrix has been used in previous research studies to appraise fall risk amongst community-dwelling older adults and provide feedback on their progress through fall risk reduction interventions.[6,10–14] Similarly, the FRA matrix is currently being used in an ongoing 8-week intervention program to categorize community-dwelling older adults, track their progress throughout the study, and provide feedback on their overall progress.[15]

Although the FRA matrix has been previously created, published, and utilized,[6,10–14] it was created in Microsoft Paint, a basic graphics program that does not allow for the ability to accurately graph individual data points, and therefore makes it difficult for use in data visualization and analysis. The progress of older adults has been previously visualized using the FRA matrix by handwritten data points on printed versions of the matrix, but this process is time-consuming and the data on the graph can become confusing if populated with multiple data points at a time. Therefore, this process needed to be optimized while keeping the design of the graph consistent.

Objective

To present and explain an R code that can be used to automatically recreate the FRA matrix for data analysis and visualization for intervention programs tailored toward older adults.

Methods

R is a free software environment that can run on all operating systems (eg, Mac, Windows, UNIX, and Linux) and was the language used to optimize FRA graphing and recreate the FRA matrix. R is commonly used for visualizing data, but no code currently exists that recreates the FRA matrix for use in data visualization and analysis. The code created for graphing the FRA matrix was created in RStudio IRE (Version 4.3.1), a free development environment for R language. The "ggplot2" and "grid" packages were used and imported into a workspace to recreate the FRA matrix. The "ggplot2" package is tailored toward producing visualizations of data and the "grid" package allows for the manipulation of graphical elements.[16]

A data frame was first created to define the numerical limits of the physiological fall risk axis (x-axis) and the self-perceived fall risk axis (y-axis) of the matrix, as defined in previous studies.[6,10–13] Within the data frame, the quadrants of the matrix were also appropriately labeled and colored to match the previously created matrix. Following the data frame, a blank black and white 2D plot was loaded into the workspace using the ggplot() and theme_bw() functions. The horizontal axis was appropriately labeled using the scale_x_continuous() function with a limit of 80 and breaks of 5. Similarly, the vertical axis was labeled using the scale_y_contінous() function with a limit of 30 and breaks of 5. The 4 quadrants of the FRA matrix were created on the blank plot using the geom_rect() and geom_text() functions in conjunction with the firstly made data frame. Various plot characteristics, such as axes title positions, and plot margins, were defined through arguments within the theme() function to ensure readability of the matrix. The 4 quadrants were separated by dashed lines using the geom_segment() function.

The ability to add individual data points within the created FRA matrix was implemented through the creation of a separate data frame. Data points for each individual are determined using their balance score from the BBS (physiological fall risk) and their Short FES-I score (self-perceived fall risk) at a specific point in time. Scoring of the Short FES-I is the only form of data pre-processing required when generating data points. The addition and removal of data points can be changed by a researcher through the created data frame. The created code also contains a function that sequentially labels data points based on specific points in time (eg, Milestone 1, Time Point 1, May 3rd, etc), which can also be altered by a researcher.

The grid.newpage(), grid.draw(), and grid.text() functions were utilized to create additional text markings on the axes outside of the graph to define low and high values for each of the axes for easier readability and understanding when presented to older adults. Finally, the pdf() function allows a researcher to create a PDF file of the FRA matrix for use as feedback for older adults or data visualization for research purposes. The developed code is shown in detail in a GitHub repository (https://github.com/jsuarez2046/FRA-matrix/tree/main) and the Supplementary Materials.

Results

The code presented in this study can recreate the previously designed FRA matrix in R as seen in Figures 1 and 2.[6,10–13,15] The code is designed to create the FRA matrix and populate it with the data of study participants, if needed, instantaneously. The code is an improvement upon the previous method due to its ability to quickly graph data points and add supplemental text in and around the graph itself while maintaining clarity and readability. Data points that are added can be appropriately labeled to represent certain events that take place during a study. An example of an FRA matrix with sample data is shown in Figure 2.

Discussion

The purpose of this study was to describe the recreation of the FRA matrix in R, which provides researchers and clinicians with a tool that allows for easier data visualization and analysis. When utilizing the matrix for intervention programs

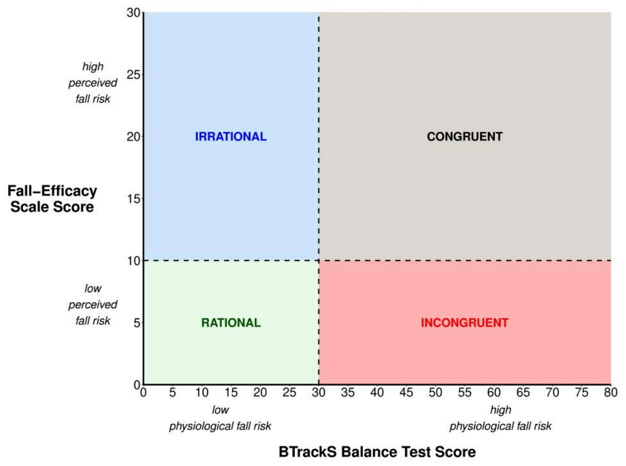

Figure 1. Fall Risk Appraisal (FRA) matrix (Blank).

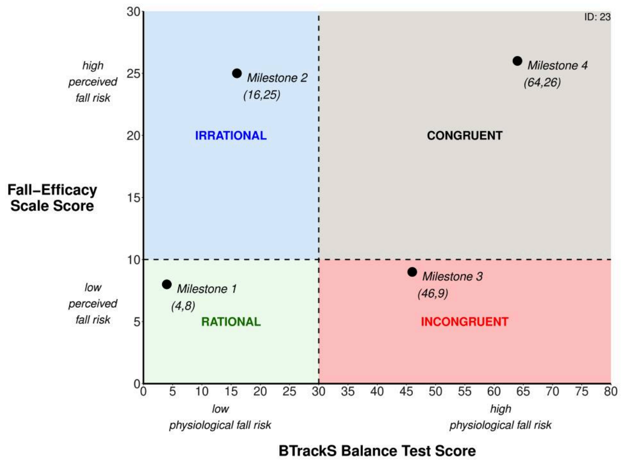

Figure 2. Fall Risk Appraisal (FRA) matrix populated with sample data.

with older adults, researchers and clinicians can quickly add data points onto the matrix itself. This allows for faster delivery of feedback, as BBS and Short FES-I scores can be quickly inputted immediately after assessment and visualized on the FRA matrix. The FRA matrix can be used for older adults as long as they are able to perform a static balance test and complete the Short FES-I questionnaire. Compared to the previous method of printing the FRA matrix from Microsoft Paint and handwriting data points, the created R code will streamline the graphing process and improve data visualization within the FRA matrix for research and clinical practice.

The FRA matrix serves 2 primary functions: to be used as a form of feedback and visualization of the categorization of older adults based on their level of FOF and physical balance, as well as to be used to visualize longitudinal data for multiple older adults in a study. The ability to automatically plot multiple data points, as well as corresponding labels, in the matrix prevents any difficulty in reading the graph by creating a cleaner visualization of the data. Although the R code is designed to recreate the FRA matrix specifically, it is beneficial to have the detailed code available to allow for quick changes to the graph for specific needs, such as for improved readability. When using the code, researchers and clinicians are encouraged to ensure the readability of the FRA matrix by tailoring different characteristics of the matrix to suit the needs of older adults using the presented code. Actions that promote readability include enlarging axes label sizes, adjusting the white space around the matrix itself, adjusting the colors of the quadrants, and adding additional participant information in and around the matrix.

Conclusions

The created R code accurately recreates the FRA matrix instrument in R, while also allowing for the addition of individual data points for improved data visualization and analysis. The presented code will streamline the process of graphing the data for older adults who are participating in intervention programs on the FRA matrix, as well as ensure the readability of the instrument when providing feedback. The recreated FRA matrix can help clinicians categorize older adults and identify those who have a mismatch or maladaptive FRA quicker and more accurately than our previous paper-pencil traditional method.

Author contributions

Jethro Raphael M. Suarez conceived the research idea, developed the R code that recreated the FRA matrix, analyzed the results, as well as drafted and edited the manuscript. Kworweinski Lafontant and Amber Blount contributed to the formal analysis, analyzed the results, and edited the manuscript. Joon-Hyuk Park analyzed the results and edited the manuscript. Ladda Thiamwong acquired funding, supervised the study, analyzed the results, and edited the manuscript. All authors reviewed the manuscript and approved the final version of the manuscript.

Supplementary material

Supplementary material is available at *JAMIA Open* online.

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Conflicts of interest

The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The organizations mentioned had no roles in the design of this study.

Data availability

R software and RStudio software are freely available and can be downloaded at https://cran.rstudio.com/ and https://posit.co/download/rstudio-desktop/, respectively. The created R code that can recreate the FRA matrix can be found at https://github.com/jsuarez2046/FRA-matrix/tree/main.

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