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PREVALENCE OF POTENTIAL RISK OF FALLS AND INACTIVATION OF THE TRANSVERSUS ABDOMINIS MUSCLE AS A RISK FACTOR IN A COMMUNITY-DWELLING ELDERLY POPULATION

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Abstract
Objectives
Falls are the leading cause of unintentional injury-related deaths in the elderly; hence, prevention of falls is an important public health issue. There is however a need to evaluate the potential risk of falls and associated predictive risk factors in the elderly. Current evidence has shown that inactivation of the transversus abdominis (TA) results in loss of balance and falls, particularly in the elderly. Thus, this study determined the prevalence of the potential risk of falls and its correlation with inactive TA among selected community-dwelling elderly.
Methods
This study screened 112 male and female participants aged 65 years and above for the potential risk of falls using the fall prediction tool for the elderly. Seventy-three participants with a high risk of falls were screened using ultrasonography for transversus abdominis muscle activation.
All data were summarized and analyzed using descriptive statistics of mean, percentage, and standard deviation. Principal Component Analysis (PCA) was used to determine the association of age, body mass index (BMI), chair stand test (CST), timed up and go test (TUG), four-stage balance test (FSB), and fall prediction tool (FPT) with transversus abdominis activation.
Results
The prevalence of risk of falls among the participants was 73%. Analysis of principal components to determine the correlation of age, body mass index (BMI), chair stand test (CST), timed up and go (TUG), four-stage balance

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(FSB), and fall prediction tool (FPT) with the activation of the transversus abdominis showed that FSB had excellent quality representation, whereas CST and FPT had good quality representation. All these had positive correlations with the activation of the transversus abdominis.

Conclusion

This study identified inactivation of the transversus abdominis as an intrinsic factor for the potential risk of falls in community-dwelling elderly

Key Words

Body mass index, Chair stand test, Fall prediction tool, Four-stage balance test, Timed up and go, transversus abdominis

1. Introduction

Fall related injury in the elderly has been recognized as a major public health issue (Gale, Cooper, & Sayer, 2016; Pengpid & Peltzer, 2018; World Health Organization (WHO), 2021). The value of independence in the elderly cannot be overemphasized as a fall can drastically reduce their ability to self-care and limit participation in physical and social activities. Falls are the leading cause of unintentional injury-related deaths and non-fatal injuries in people aged 65 years and older, constituting 55% of all cases (Center for Disease Control and Prevention (CDC), 2015). The causes of falls are inter-related and multi-factorial as falls result from complex interactions of risk factors, one of these being the natural aging process, which is accompanied by changes in cognitive and sensory domains that lead to balance impairments (Turner, Chander & Knight, 2018). The effect of these changes affects muscle function by decreasing motor function, reducing muscle strength and endurance, and thus affecting complex movements resulting in falls (Mahmoodabad, Zareipour & Beigomi, 2018).

Current evidence has shown that a delayed activation of the transversus abdominis, a core stabilizing muscle results in loss of balance and falls especially in the elderly (Ponde, Agrawal & Chikte, 2021). A prior study has shown that the transversus abdominis does not show any significant age rela-related atrophy but did demonstrate a decrease in contractile tissue and timing which affect balance in the elderly (Singer, Prentice & Mcllroy, 2016). Studies have shown that when there is weakness of the transversus abdominis due to old age, there will be delayed onset of its activation which leads to inefficient muscular stabilization of the spine, impaired balance and , and consequent falls in the elderly (Maitri and Geeta, 2017).

Implementing an evidence-based fall prevention program could appreciably decrease the incidence and healthcare cost of fall injuries as well as greatly improve the quality of life of the elderly. Before this can be achieved, there is a need to first evaluate and routinely screen the elderly for the potential risk of falls in respective physiotherapy clinics irrespective of the initial condition of presentation of the elderly to the clinics.

This study thus determined the prevalence of the potential risk of falls and the correlation with inactive transversus abdominis among selected community-dwelling elderly population.

2. Materials and Methods

2.1 Participant Selection

This study involved 112 male and female elderly individuals who were recruited from two randomly selected communities: the Tanke community from the Ilorin south Local Government Area and the Adewole community from the Ilorin west Local Government Area in the Ilorin metropolis, Kwara State. Included in this study were participants who were 65 years and older and could walk independently with or without a walking aid. Participants were able to understand basic instructions and perform the basic exercise tests independently. Excluded were participants who could not walk 3 metres and those who had poor eye sight.

2.2 Materials

The instruments used included a standard arm chair, which is a wooden chair of 44–47 cm in height having two arms with a combined arm height of 65 cm. This was used for the participants to sit on for the timed-up and go (TUG) test and the chair stand test. In addition, a Diagnostic Ultrasound Machine (SIEMENS, USA with model number Sonoline G60S) with a 13.5 MHZ linear array was used to evaluate the activity of the transversus abdominis muscle.

2.3 Methods

This was a cross-sectional study. Ethical approval was obtained from the institutional Ethics Review Committee **(ERC PAN/2022/02/0233)**. Informed consent was obtained from each participant before inclusion in the study. Confidentiality of all information obtained from each participant was ensured as data were de-identified and securely stored.

2.4 Determination of the Sample Size

Fisher's formula for sample size determination was used to calculate the sample size for this study.

$$n = \frac{z^2pq}{d^2}$$

Where n = the desired sample size

z = the standard normal deviation set at 95% (1.96)

p = proportion of the target population set at 30% (Dionyssiotis 2012, Turner et al., 2018).

q = 1 p = 1 0.3 = 0.7

d = Degree of accuracy desired 0.09

$$n = \frac{(1.96)^2(0.3)(0.7)}{(0.09)^2} = \frac{0.8067}{0.0081}$$

n = 99.59 + 9.959 (10% attrition rate)

n = 109.5

2.5 Sampling Technique

A multistage sampling technique was employed in the selection of participants for this study. Simple random sampling was used to select two local government areas (LGAs), the Ilorin south and Ilorin west LGAs, out of the three LGAs in the Ilorin metropolis of Kwara State. One community was randomly selected using fish-bowl sampling in each of the selected LGAs: the Tanke community in the Ilorin south LGA and the Adewole community in the Ilorin west LGA. Cluster sampling of a quarter (¼) was selected in each community, and an equal number of samples was selected from each Cluster. A total number of willing elderly participants were recruited from the two communities.

2.6 Research Methodology

In the two communities, courtesy calls were made to the community leaders, and the purpose and benefits of the research were explained to them. Permission to conduct the study in the community was granted and and they assisted in mobilizing the elderly while also participating in the research. Assessment and baseline socio-demographic documentation with the use of data form occurred at the community health centers, while ultrasonography evaluation was conducted in a renowned Radio- diagnostic center within the metropolis.

2.7 Determination of prevalence of the potential risk of falls and fall prevalence

One hundred and twelve participants were recruited and screened for the potential risk of fall using a fall prediction tool for the elderly (Shubert et al.,2017) and the scores of three standard functional assessment protocols which are the 30 seconds chair stand, timed up and go (TUG), and the four-stage balance test were taken (Phelan, Mahoney, Voit & Stevens, 2015). Eighty-two participants who were categorized as having a high risk of falls were scheduled for transversus abdominis muscle activation assessment using a Siemens Sonoline G60S ultrasound machine by a consultant and Professor of Radiology. Seventy-three participants were finally screened for transversus abdominis muscle activation in which 60 participants had inactive transversus abdominis.

2.8 Fall Prediction Tool: This was used to screen the elderly for the potential of a fall. It is a combination of tools that assess a participant's fall history, general health status, satisfaction with current activity level, confidence about keeping oneself from falling, and difficulty in performing functional activities.

Standard functional assessment protocols of the 30 Second Chair Stand test were used to assess participants' **strength**, Timed Up and Go (TUG) to assess participants' **mobility**, and the Four-Stage balance test was used to assess participants' **balanc**e. Participants with low scores in these tests were at increased risk of falling, and those in this category were further subjected to ultrasound screening of their transversus abdominis muscles.

2.9 Thirty Second Chair Stand Test: This test assesses lower limb strength and endurance. A below average rating indicates a high risk for falls (Phelan, Mahoney, Voit & Stevens, 2015).

2.10 The Timed Up and Go (TUG) Test: This test assesses older adult mobility. An elderly person who takes 12 s or more to complete the TUG is at a high risk of falling (Phelan, Mahoney, Voit & Stevens, 2015).

2.11 Four-Stage Balance Test: The purpose of this test is to assess static balance. The four progressive positions are standing with feet side by side (feet together stand), standing with the instep of one foot touching the big toe of the other foot (semi-tandem stand), standing with one foot in front of the other with the heel touching the toe (tandem stand), and standing on one foot (one leg stand). Inability to hold the tandem stance for at least 10 s increases the risk of fall (Phelan, Mahoney, Voit & Stevens, 2015).

2.12 Ultrasonography: The participants were in crook lying position with the abdomen exposed. Ultrasound gel was applied to the transducer and placed over the right abdomen superior to the iliac crest in the midaxillary line in a transverse position (Teyden et al., 2008; Selkow et al., 2017). The transversus abdominis position was standardized on the ultrasound screen by visualizing its medial edge on the far right of the ultrasound screen. Six images were taken per participant; three resting images were captured at the end of exhalation to limit the effect of respiration on muscle thickness. The participants then performed the abdominal draw-in maneuver (ADIM), and three images were recorded during contraction. Transversus abdominis activation was defined as the ratio of transversus abdominis thickness change from a contracted position during the abdominal draw-in maneuver to a resting position calculated as contracted state/resting state. An activation value 2 indicated inactive transversus abdominis, whereas a value 2 indicated active transversus abdominis (Selkow et al., 2017). A single musculoskeletal sonographer performed all the imaging, and the results were categorized.

2.13 Data Analysis: All data were summarized and analyzed using descriptive statistics of mean, percentage, and standard deviation. Information was presented in the form of tables and charts. Principal Component Analysis (PCA) was used to determine the association of age, body mass index (BMI), chair stand test (CST), timed up and go test (TUG), four-stage balance test (FSB), and fall prediction tool (FPT) with transversus abdominis activation. Three (3) principal components with cumulative variance of more than 70% were retained. The eigenvectors (rotation matrix) were determined to show the correlation between the raw and transformed variables, and a correlation coefficient level above 0.4 was deemed important.

3. Results:

One hundred and twelve (112) elderly individuals between 65 and 84 years of age participated in this study. Fifty-two (46.7%) were males and 60 (53.3%) were females. Table 1 shows the Socio-Demographic characteristics of the study participants, while Table 2 depicts the clinical parameters of the participants, which included the Mean ± SD of age (years), height (m), weight (Kg) and BMI (Kg/m2), which were 70 ± 4.3, 1.62 ± 0.11, 67.5 ± 13.78 and 26.18 ± 8.41 respectively.

The distribution of the pparticipant's' BMI is shown in Figure 1. The prevalence of risk of falls among the participants was 73%, which is the average of the total score of chair stand inference (91.7%), TUG inference (86.7%, four-stage balance inference (58.3%, and fall prediction tool (56.0% as described in Table 3.

Table 4 shows the chi-square analysis of the risk of falls with activation of the transversus abdominis muscle, which showed a significant association with TUG scores. Table 5 shows the eigenvalues for each principal component as 1.5648, 0.9959, and 0.9586 for PC1, PC2, and PC3, respectively. The percentage total explained variances by each component were 40.81, 16.53, and 15.31, respectively. The three principal components accounted for 72.66% of the total explained variations.

Figure 2A is a two-dimensional billot of the principal component analysis of the participants. Although three principal components were considered in this study, the first two principal components were plotted for easy illustration and visualization. The participants clustered into groups of "Active" and "Inactive" to transversus abdominis, figure 2A. Figure 2B is a factor map that shows the quality of representation of the variables in PC1 and PC2. BMI was low in quality, Age and TUG were moderate, CST and FPT were high, and FSB was excellent in quality of representation, Figure 2B.

Table 1: Socio-Demographic characteristics of study participants (N=112)

Variables	**Frequency**	**Percentage (%)**
Age groups (Years)		
65–74	99	88.30
75–84	13	11.70
Sex		
Male	52	46.70
Female	60	53.30
Ethnicity		
Yoruba	108	96.70
Others	4	3.30
Level of Education		
Primary	28	25.00
Secondary	32	28.30
Tertiary	48	43.30
Postgraduate degree	4	3.30
Living status		
Living with people	112	100.00
Living alone	0	0.00
Use of the assisted device		
Yes	0	0.00
No	112	100.00

Table 2: Clinical parameters of the study participants

Variables	Minimum	Maximum	Mean ± SD

Age (years)	65.00	80	70.00 ± 4.30
Weight (Kg)	39.00	120	67.50 ± 13.78
Height **(**m)	1.00	1.83	1.62 ± 0.11
Body mass index **(**Kg/m^2)	17.10	30	26.18 ± 8.41
Systolic blood pressure (mmHg)	109.00	150	129.73 ± 11.53
Diastolic blood pressure (mmHg)	70.00	102	84.27 ± 7.89

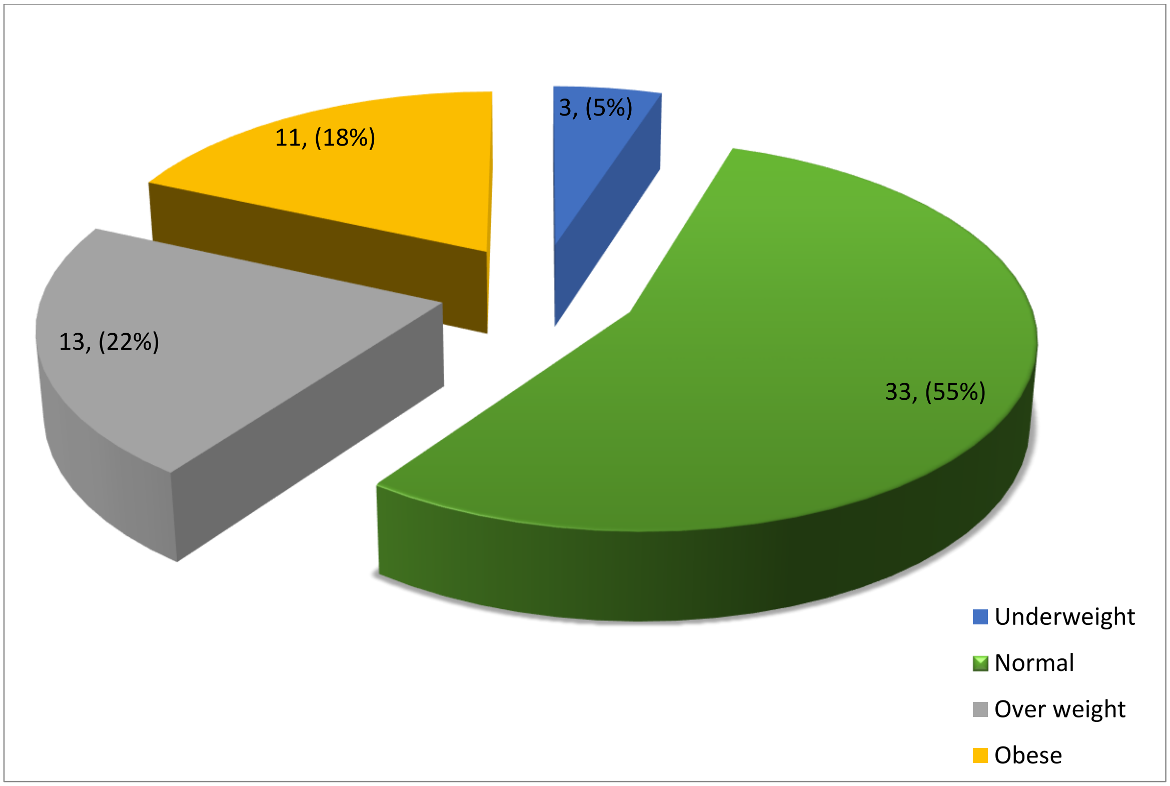

Figure 1: Presentation of participants by Body Mass Index

Table 3: Prevalence of Potential Risk of Falls among Study Participants using Functional Assessment Tools

Variables	**Frequency (n)**	**Percentage (%)**
Chair stand inference		
Below average	103	91.70
Average	6	5.00
Above average	3	3.30
TUG inference		
High risk	97	86.70
Low risk	15	13.30
Four-stage balance inference		
High risk	65	58.30
Low risk	47	41.70

Key: TUG- Timed-up and Go.

Table 4. Risk of Falls and Tranversus Abdominis Activation

Parameter	N	Overall, N = 73	Transverse Abdominis Active, N = 13	Inactive, N = 60	p-value
Age [Years]	73	70 (67, 72)	69 (66, 72)	70 (68, 73)	0.4
Body Mass Index [Kg/m^2	73	24.0 (22.2, 28.3)	23.3 (22.0, 24.1)	24.3 (22.5, 28.9)	0.28
Chair Stand Test [seconds]	73	10 (8, 10)	10 (9, 11)	10 (8, 10)	0.45
TUG Scores [seconds]	73	13.00 (12.40, 14.0)	12.45 (12.11, 13.0)	13.20 (12.5, 14.4)	0.021
Four-Stage Balance	73	39 (53%)	4 (31%)	35 (58%)	0.071
Fall Prediction Tool	73	69 (63, 75)	69 (63, 76)	69 (65, 75)	0.73

Median (IQR) or Frequency (%)

Wilcoxon rank sum test; Pearson's Chi-square test

Table 5: Principal Component Analysis Eigenvalues and Eigenvectors

	PC1	PC2	PC3	PC4	PC5	PC6
Normalized Eigenvalue	1.5648	0.9959	0.9586	0.8034	0.7755	0.6276
Total Variance Explained (%)	0.4081	0.1653	0.1531	0.1076	0.1002	0.0657
Cumulative of Variance Explained (%)	0.4081	0.5734	0.7266	0.8341	0.9344	1

Eigenvectors	PC1	PC2	PC3	PC4	PC5	PC6
Age	**-0.4663**	-0.1146	0.1364	-0.1031	0.8186	0.2647
BMI	0.231	-0.1239	**0.963**	-0.0138	-0.0579	0.0309
Chair Stand Test	**0.4711**	0.3545	-0.0141	0.2537	0.5311	-0.5529
TUG Score	**-0.4373**	-0.3282	0.0781	0.7548	-0.1037	-0.3384
Four-Stage Balance	-0.2731	**0.8302**	0.1591	0.3095	-0.1284	0.3141
Fall Prediction Tool	**0.4913**	-0.2212	-0.1517	0.5093	0.1312	0.6041

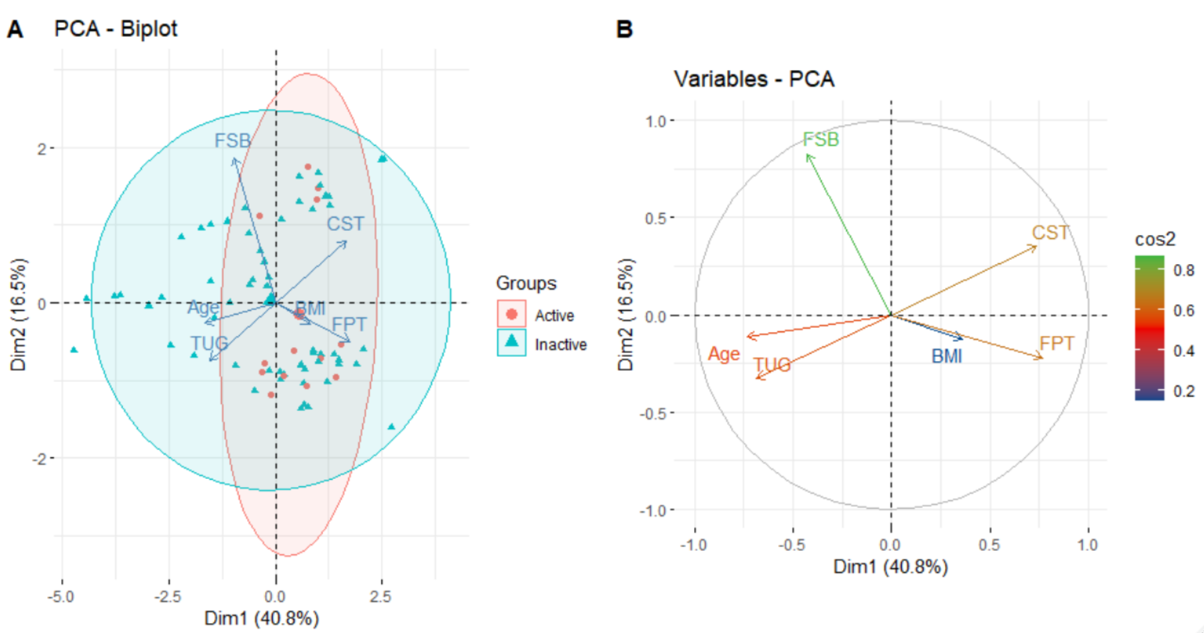

Figure 2: Biplot and Factor Map.

BMI was low in quality, Age and TUG were moderate, CST and FPT were high, and FSB was excellent in quality of representation in the transversus abdominis.

4. Discussion

The global rapid growth of the elderly population has resulted in a high prevalence of falls in this population, although it is potentially modifiable. Several studies have shown the ever-increasing falls in the elderly and are continuous efforts and studies aimed at reducing falls and its associated burdens in the elderly. Previous studies have shown significant relationship between an increase in the potential of falls and actual falls in the elderly (Dionyssiotis, 2012; Rubenstein & Josephson, 2006; WHO, 2021). Therefore, this has provided preliminary data on the prevalence of the potential risk of falls and its association with inactive transversus abdominis among community-dwelling elderly in Nigeria.

Among the 112 participants recruited for this study, 73% had a high risk of falls (chair stand inference- 91.7%, TUG inference- 86.7%, four-stage balance inference- 58.3%, and fall prediction tool- 56.0%). This agrees with a study that used a hybrid of OEP among elderly in the United States in which 86.5% of participants are at high risk category for the TUG test, and 69.2% are at high risk for the Chair Rise (Shubert et al., 2017), but contrary to the report of Dhargave and Sendhilkumar [16], who used fall risk assessment tool (FRAT) and reported that among the 163 elderly patients recruited for their study, only 37.42% of them had a high risk of falls. The difference in findings could either be due to the assessment tool that was used or the fact that the participants were recruited from four geriatric homes in India which were regimented, with regular medical care and other support while the participants in our study were community-dwelling elderly who were exposed to more environmental risk factors, including home hazards such as narrow steps, slippery surfaces of stairs, loose rugs, and insufficient lighting. In addition, they were exposed to hazards in public places such as poor building design, cracked or uneven sidewalks, and poor lighting. These factors are very pertinent as it has been reported by prior studies that increases in the propensity to fall are mostly due to interactions between intrinsic and extrinsic factors (Dionyssiotis, 2012; PHAC, 2014; WHO, 2021).

The natural aging process is accompanied by changes in cognitive and sensory domains that lead to balance impairments, resulting in falls (Turner et al., 2018). These changes also affect muscle function by decreasing motor function, reducing muscle strength and muscle endurance, and thus affecting complex movements, resulting in falls in the elderly (Mahmoodabad, Zareipour & Beigomi, 2018). Traditionally, exercises to the lower limb muscles have been administered to patients to improve balance and prevent falls, especially in the elderly (Ferraro, Garman, Taylor, Scott & Kadlowec, 2019). However, current evidence has shown that inactivation of the transversus abdominis, a core stabilizing muscle results in loss of balance and falls particularly in the elderly (Ponde, Agrawal & Chikte, 2021).

The transversus abdominis, which is the deepest layer of the abdominal wall, increases the intra-abdominal pressure and places tension on the thoracolumbar fascia when contracted, thereby stabilizing the spine (Maitri & Geeta, 2017). The transversus abdominis activates prior to the initiation of movement of the upper and lower limbs, and a previous study reported that when there is weakness of the transversus abdominis due to old age, there will be delayed onset of its activation which lead to inefficient muscular stabilization of the spine resulting in impaired balance and consequent fall in the elderly (Maitri & Geeta, 2017). Thus, the transversus abdominis has been described as the most important muscle for maintaining spinal stability during dynamic and static activities (Baek SO, Ahn SH, Jones R, Cho HK, Jung GS, Cho YW, et al, 2014; MacKenzie JF, Grimshaw PN, Jones CDS, Thoirs K, Petkov J, 2014)

Since prior studies have reported a significant relationship between an increase in the potential risk of falls and actual falls in the elderly (Dionyssiotis, 2012; Rubenstein & Josephson, 2006; WHO, 2021), this study also investigated the correlation of transversus abdominis inactivation with the potential risk of falls using validated tools that predict the potential risk of falls in the elderly.

Analysis of principal component to determine the correlation of age, body mass index (BMI), chair stand test (CST), timed up and go (TUG), four-stage balance (FSB), and fall prediction tool (FPT) with the activation of the transversus abdominis showed that FSB had excellent quality representation, whereas CST and FPT had good quality representation. All these had positive correlations with activation of the transversus abdominis, thus implying that the higher the scores of the participants in these tests, the more active the transversus abdominis muscles. The core muscles of the trunk are responsible for maintaining postural control, and prior studies have shown a significant relationship between good core muscle strength and balance, which intrinsically contribute to fall prevention (Ferraro et al., 2019; Maitri & Geeta, 2017). This clearly supports our findings that FSB had a very strong correlation with the activation of the transversus abdominis.

Muscle mass and strength have been reported as two crucial factors in healthy aging; thus, older people with lower muscle mass and muscle strength are more likely to have a greater loss of mobility (Visser M, Goodpaster BH, Kritchevsky SB, Newman AB, Nevitt M, Rubin SM, et al., 2005) and an increased risk of falls (Landi F, Liperoti R, Russo A, Giovannini S, Tosato M, Capoluongo E, et al., 2012). This could explain why age and TUG, which is designed to evaluate mobility, had a negative correlation with transversus abdominis activation; therefore, higher TUG scores would indicate inactive transversus abdominis. To underscore this, as seen in the Factor map, age and TUG are negatively correlated to show that with an increase in age comes decreased mobility. All the tools used in this study are validated tools that predict the potential risk of falls in the elderly, thus, their significant correlations with transversus abdominis muscle activation as seen in this study imply that inactivation of the transversus abdominis muscle is also a major predictor of the potential risk of falls in the elderly.

5. Conclusion

This study identified TA inactivation as an intrinsic factor for potential risk of falls in community-dwelling elderly.

6. Limitations of the Study

The prevalence of falls and risk of falls identified in this study constitute preliminary data due to the small and localized study population. This study is expected to serve as a template for future studies on the prevalence of falls among the elderly in Nigeria.

In addition, a number of the participants that were screened initially and had potential risk of falls were not available to undergo ultrasonography assessment of the transversus abdominis muscle.

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Figure Legend

Figure 1: Presentation of participants by Body Mass Index

Figure 2: Biplot and Factor Map