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Yoga versus neuromuscular coordination exercise in improving fall predictor parameters and nerve growth factor levels among adult population: a randomized controlled trial

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ABSTRACT

Background and purpose: The incidence of fracture-related falls in young adults has been increased and the population with walking disorders has an increased risk of falling. It is very important to improve fall predictor parameters early in adulthood to reduce the risk of falling and injury in the future. This study aims to explore the differences of effectiveness between yoga and neuromuscular coordination exercise in improving several fall predictor parameters and Nerve Growth Factor (NGF) levels.

Methods: This study was a randomized controlled trial involving 30 participants who met the inclusion and exclusion criteria. Participants were divided into two groups randomly. Group one was given yoga training intervention and group two was given neuromuscular coordination exercise. Participants` gait speed measurements were carried out using Shuttle Run Test. Participants` agility measurements were carried out using Hexagonal Obstacle Test. Participants` visual and auditory reaction time measurements were carried out using Whole Body Measuring equipment II type TKK – 1264 B. NGF measurement used the ELISA technique.

ResultsPaired sample Wilcoxon test showed yoga training was effective in improving all fall risk predictor parameters and NGF with p<0.05, but neuromuscular coordination exercise only showed improvement in one fall predictor parameter, namely speed. The unpaired sample Mann Whitney test proved that yoga training was significantly more effective with p<0.05 compared to neuromuscular coordination exercise in improving fall risk parameters, namely agility, visual reaction time, auditory reaction time, but not more effective in improving speed gait and NGF level.

Conclusion: The We conclude that yoga training is the most effective exercise in improving fall risk parameters, namely agility, visual and auditory reaction time. Yoga training is a promising intervention in improving various aspects of fall risk.

Keywords: Yoga, neuromuscular coordination, fall risk predictor, nerve growth

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INTRODUCTION

Issues regarding limitations and disabilities related to physical function are mostly studied in the elderly group, but recent scientific evidence states that middle age is a critical period of onset of various physical limitations and disabilities.[1] Epidemiological data show that physical limitations are common in middle age so that middle age is an ideal time to provide interventions aimed to prevent or delay physical limitations.[2] Falls are an event that requires preventive intervention and further research. Most research focuses on preventing falls in the elderly, but research on fall prevention in young people remains very limited.[3] Recent research shows that falls are not only a major problem for the elderly population but also in young adults. The incidence of fracture-related falls in young adults increased by 25% over the 10-year period from 2000 to 2010.[4] Gait speed is one of the predictors of falls, where the population with walking disorders has an increased risk of falling.[5] Gait speed is a mobility parameter that is simple, fast, reliable, feasible and have sufficient predictive validity to fall in the future.[6] Previous evidence has been demonstrated that gait speed is a clinically meaningful tool for testing neuromotor control of mobility and overall physical performance. Gait speed less than 0.56 m/s is predicted to fall. Gait speed has been scientifically proven as a screening tool to predict risk of falls,[7] so that by improving gait speed from an early age, it can be a preventive effort for falls in the elderly in the future. Agility is also a fall predictor parameter, where decreased agility can increase the risk of falling. Agility measurement can help to predict the risk of falls. Agility declines more rapidly after the age of 50.[8]

Another fall predictor parameter is reaction time. A retrospective study showed that slow reaction time was the strongest discriminator in a person's fall status. There is a relationship between slow reaction time and repeated falls. Reaction time can affect falls where there is an impaired response to threats of balance in everyday situations that require supraspinal processing. Indeed, slow voluntary reaction times have been shown to be a predictor that distinguishes between falling and non-falling populations.[9] A study has proven a significant relationship between auditory reaction time, static and dynamic balance which is a major factor in the incidence of falls.[10] A study showed that stepping disorder occurs in the elderly, especially in people with a higher risk of falling and balance disturbance so that preventive efforts are needed to identify people who are at high risk of falling and to accurately determine risk factors for falls early.[11]

Nerve growth factor (NGF) is a neurotrophic factor that plays a role in the plasticity of cholinergic neuron cells in the basal forebrain.[12] NGF is a neurotropin that is important in the formation of the structure, function and survival of nerve cells.[13] Control of trophic factors of cholinergic function can affect plasticity significantly. There are several mechanisms underlying neuroplasticity related to motor control, namely NGF where it can affect cholinergic activity, and thereby induce long-term potentiation (LTP).[14] NGF plays a role in sensory integration in the neuromuscular coordination of movements associated with attention and motor planning functions so it is important in movement neuromuscular coordination,[15] which is very important in walking speed, agility and reaction time.

Yoga training is an intervention that has been scientifically proven to stimulate and improve various components in balance and neuromuscular coordination functions so as to reduce the risk of falling. Yoga training is an intervention that can stimulate muscle structure and increase muscle strength in the body and extremities,[16] stimulates the structure of muscle tissue and its surroundings,[17] and increases somatosensory function.[18] Based on studies, neuromuscular coordination exercise is also can improve various components that play a role in walking speed, through increasing intra and interlimb neuromuscular coordination,[19] thus it also plays a role in reducing the risk of falling. This study explores the difference of effectiveness between yoga training and neuromuscular coordination exercise in increasing fall predictor parameters and NGF so that it is an early fall prevention effort.

METHOD

Study design

This research is a randomized controlled trial with the method of pre-test and post-test control group design, which samples were adult population and conducted at Denpasar, Bali, Indonesia.

Population, sample, source of data

Samples recruitment strategy is summarized using the consort statement flow diagram presented in Figure 1. This research involved 30 samples that selected using simple random sampling method with random number table. The number of samples assessed for eligibility was 36 people and 6 people were excluded because they refused to participate in the study, therefore, the number of randomized samples were 30 people. The study involved two arms, yoga group and control group. The yoga group was given a yoga training while the control group was given a neuromuscular coordination training. Samples were divided into 2 groups randomly. The random allocation technique that we used was block randomization and the block size was not stated in the protocol. Samples allocated to yoga group were 16 people, while those allocated to control group were 14 people. There were 5 samples who discontinued intervention because they did not attend exercise for more than 3 times, therefore, the number of participants analyzed in the yoga group was 13 while the control group was 12 people. An explanation of the procedures and benefits of the study was conducted to all participants before the study began. Participant’s agreement was showed by signing the informed consent.

Participants in this study were adult population in Denpasar City, Bali Province, Indonesia. The participants were established according to eligibility criteria, which ages are 36-55 years, were able to follow exercise and to perform according to instructions, muscle strength within normal limits, sensory function within normal limits, neuromuscular coordination function within normal limits, able to read, write and communicate well. Participants were excluded if at the time of examination, they participated in a physical exercise program other than the given intervention, had a history or current injury and had a physical disability. Participants were dropped out when they were unable to complete the intervention, suffered injuries during the study, or resigned by themselves.

Data collection techniques and research instruments

The guideline used for body mass index (BMI) classification is BMI criteria of Asia Pacific.[20] Weight measurements were carried out using digital body weight scale by Omron. Height measurements were carried out using stature meter by One Med. NGF examination was carried out before and after treatment. Participants' physical activity level were measured using International Physical Activity Questionnaires Short Form (IPAQ-SF). For NGF measurement, we used human Nerve Growth Factor 96T ELISA kit ® (BT LAB, catalog no E2102 Hu). Gait speed measurements were carried out using Shuttle Run Test, while agility measurements were carried out using Hexagonal Obstacle Test. The visual and auditory reaction time measurements were carried out using Whole Body Measuring equipment II type TKK- 1264 B.

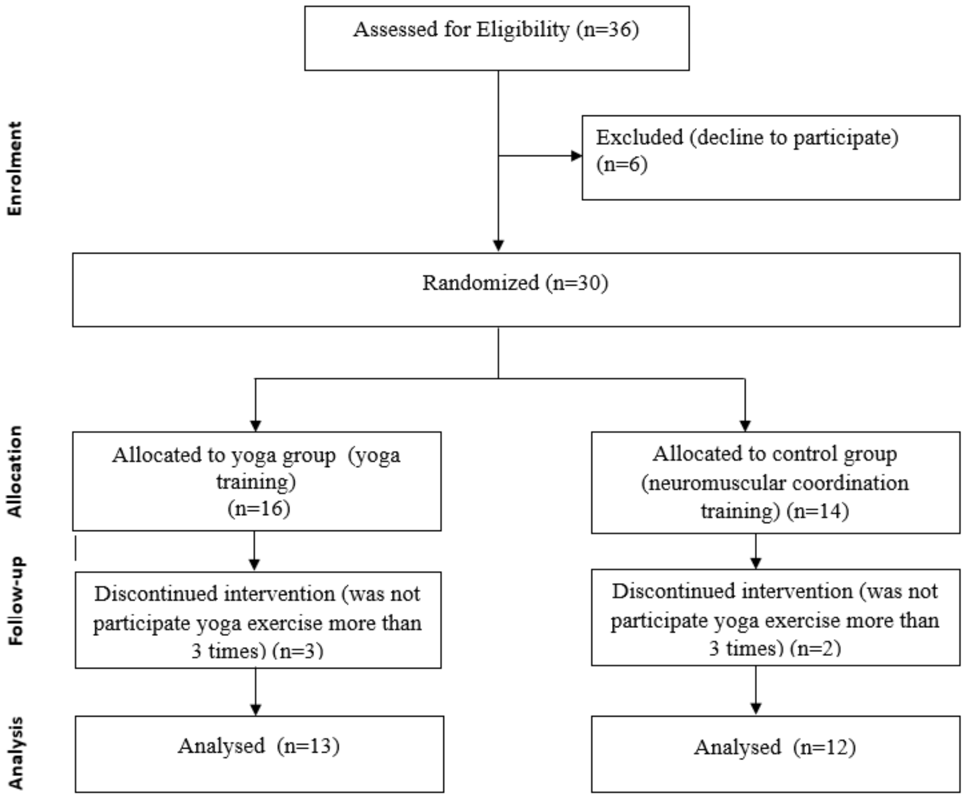

Figure 1. Diagram of participants recruitment

Blood sampling was taken twice, the day before yoga and neuromuscular coordination exercise began (pre-test) and the day after (post-test). Venous blood that had been taken using a syringe was left standing for 1-2 hours, so that serum/plasma and other blood components were separated. After 1-2 hours, a new 300 rpm centrifuge was carried out for 10 minutes. The observed formed supernatant (serum/plasma) were separated from other blood components. The supernatant was put in a 1.5 ml microcentrifuge tube and stored in the freezer -20/-80˚C. NGF measurement was conducted using ELISA technique. Preparation of reagents, samples, standard solutions and assay procedures had been carried out according to standard NGF measurement procedures.

Data analysis

The collected data were processed using the SPPSS version 25. Descriptive data test was performed, normality test was carried out using the Saphiro Wilk test, homogeneity test was carried out using Levene's test. Paired test using the Wilcoxon Sign Rank test on several parameters before and after the intervention in both groups with $p<0.05$ indicating the statistical significance. The difference test between groups using the Mann Whitney U test with $p<0.05$ indicating statistical significance.

The research has been approved by the Research Ethics Commission of the Faculty of Medicine, Udayana University with grant number 1830/UN14.2.2.VII.14/LT/2021, dated July 14, 2021.

RESULT

Based on the results in Table 1, it can be seen that the proportion of female participants is greater than men. Based on the level of physical activity that was measured with the IPAQ-SF questionnaire, most of the participants had light physical activity. Body mass index (based on Asia Pacific body mass index criteria), systolic and diastolic blood pressure of all participants are within normal limits. Table 1 also shows the results of the comparative test between the two groups on the characteristics based on age, weight, height, BMI which showed no significant difference ($p>0.05$) in these variables between both groups.

Table 1. Characteristics of participants

Characteristics	Yoga Group	Control Group	p
Gender (%)			
Male	92.31	83.33	
Female	7.69	16.67	0.332
Physical activity level (%)			
Light	61.54	75	0.476
Moderate	38.46	25	
Age (years), mean ± SD	39.08 ± 3.67	39.25 ± 3.01	0.563
Body weight (kg), mean ± SD	52.08 ± 7.31	54.25 ± 5.86	0.414
Height (m), mean ± SD	1.56 ± 0.12	1.6125 ± 0.06	0.288
BMI (kg/m^2), mean ± SD	21.28 ± 0.93	20.83 ± 1.44	0.415
Systole (mmHg), mean ± SD	118.33 ± 9.37	115 ± 11.67	0.445
Diastole (mmHg), mean ± SD	71.66 ± 5.77	74.16 ± 7.92	0.370
Gait speed (second), mean ± SD	19.26 ± 5.98	18.22 ± 2.40	0.703
Agility (second), mean ± SD	33.42 ± 10.38	26.76 ± 6.79	0.004
Visual reaction time (millisecond), mean ± SD	267.08 ± 79.76	188.41 ± 61.89	0.000
Auditory reaction time (millisecond), mean ± SD	280.16 ± 111.02	180 ± 26.92	0.001
NGF level (ng/mL), mean ± SD	88.71 ± 15.30	106.65 ± 46.30	0.064

Table 2 shows that yoga training was effective in improving all fall risk predictor parameters that we measured in our study, namely gait speed, agility, visual reaction time and auditory reaction time, where the average of these variables decreases in the post test which shows an increase in function because it is measured by calculating the speed of time, the shorter the time duration, means that better the function of gait speed, agility, visual reaction time and auditory reaction time. Yoga training is also effective in increasing NGF levels after intervention. Neuromuscular coordination exercise is not effective in increasing several predictor parameters of fall risk (agility, visual reaction time auditory reaction time) and NGF, but increasing gait speed shows significant results in this dependent test.

Table 2. Mean differences of fall predictor parameters and NGF before and after interventions

Variable	Group	Mean ± SD before intervention	Mean ± SD after intervention	p
Gait speed	Yoga	19.26 ± 5.98	16.03 ± 3.07	0.011
	Control	18.22 ± 2.40	16.93 ± 2.58	0.003
Agility	Yoga	33.42 ± 10.38	26.68 ± 7.79	0.002
	Control	26.76 ± 6.79	26.99 ± 6.43	0.937
Visual reaction time	Yoga	267.08 ± 79.76	194.33 ± 60.42	0.001
	Control	188.41 ± 61.89	201.50 ± 71.27	0.533
Auditory reaction time	Yoga	280.16 ± 111.02	208 ± 76.89	0.001
	Control	180.00 ± 26.92	183.25 ± 26.78	0.638
NGF level	Yoga	88.71 ± 15.30	139.85 ± 31.82	0.001
	Control	106.65 ± 46.30	139.57 ± 69.34	0.099

Table 3 shows the results of an independent test on the improving of all parameters data (mean difference before and after intervention) between both groups. We can conclude that the improvement in agility, visual and auditory reaction time parameter in the yoga group showed a significant difference to the neuromuscular coordination group. However, the improving gait speed and increasing NGF between the two groups did not show a significant difference. We can also conclude that the significant results in Table 3 are due to differences in the intervention in the two groups, and are not influenced by differences in the characteristics of the respondents in the two groups. This can be proven by the results of the comparative test of the characteristics of the respondents between the two groups which showed insignificant differences (p>0.05) in Table 1.

Table 3. Mean differences of fall predictor parameters and NGF between yoga and control groups

Variable	Group	Mean difference ± SD	p
Gait speed	Yoga	3.23 ± 6.54	0.703
	Control	1.29 ± 1.38	
Agility	Yoga	6.74 ± 6.80	0.004
	Control	-0.23 ± 4.61	
Visual reaction time	Yoga	72.75 ± 44.68	0.000
	Control	-13.08 ± 48.36	
Auditory reaction time	Yoga	72.16 ± 60.66	0.001
	Control	-3.25 ± 28.90	
NGF level	Yoga	51.14 ± 34.95	0.064
	Control	32.91 ± 63.27	

DISCUSSION

In this study, it was found that yoga training is more effective in improving several predictor parameters of falls compared to neuromuscular coordination exercise. From the statistical test results, it was found that yoga training is significantly more effective than neuromuscular coordination exercise in improving several predictor parameters of falls such as agility, visual reaction time and auditory reaction time ($p<0.05$). The effectiveness of yoga training in improving agility occurs because yoga training can improve several components in agility, namely coordination, muscle strength and balance. These results are consistent with previous research which concluded that yoga training is effective in improving coordination, muscle strength and balance in a healthy population.[21] Yoga training is effective in improving coordination based on the fact that yoga training can improve higher cognitive functions such as executive function, mental function, and working memory.[22] Yoga training combines the practice of body postures with mindful breathing which can help develop mental focus and connect body, mind and spirit.[23] The increase in muscle strength that occurs in Surya Namaskar Yoga is due to the fact that all muscles of the body and extremities undergo alternate stretching and physical loading in performing various asanas in Surya Namaskar Yoga, thereby providing the benefits of a faster increase in muscle strength. Some of the asanas in Surya namaskar yoga involve continuous contraction of many muscles of the body and extremities.[24] Another component of agility is balance. Surya namaskar yoga training has been shown to improve balance function. Previous study reported that yoga training could improve the function of the sacculo-collic pathway using Cervical Vestibular Evoked Myogenic Potential (cVEMP) analysis. The sacculo-collic pathway plays an important role in balance and posture function, while cVEMP is a diagnostic tool used to examine the function of the sacculo-colic pathway.[25]

This study also proves that yoga training is significantly more effective than neuromuscular coordination exercise in improving reaction time. This is based on the fact that yoga training can improve executive attention function, where yoga training facilitates increased activation of the anterior cingulate cortex during rest in yoga practitioners. Yoga training can also increase the overall activation of various brain waves.[22] Reaction speed consists of components of dynamic balance, cognitive functions related to motor executives and the speed of delivery of sensory stimuli, where yoga training has been shown to significantly improve these reaction time components. This is consistent with the previous research findings concluded that yoga training can improve motor performance and body awareness. Yoga training can increase motor learning rate, speed and accuracy in performing motor tasks by increasing attention, sensory awareness, enteroception and reducing stress so as to improve sensorimotor control functions.[26]

In this study, our finding shows insignificant difference between the two groups on the NGF serum levels. This shows that yoga training is not more effective to increase NGF serum level. This is in line with the results of various studies showing that both yoga training and neuromuscular coordination training are forms of physical training that can increase serum NGF levels.[27,28] Yoga training and neuromuscular coordination training are able to improve serum NGF levels because they can induce central and peripheral nervous system adaptation. Yoga training that has been proven to induce the central and peripheral nervous system through improving proprioceptive function. Yoga training trains body movements and cognitive functions so as to improve kinaesthetic abilities. Structures that also play a role in proprioceptive function are the visuomotor, supplemental motor, and premotor areas, where yoga and meditation training have been shown to improve the function of these various cortical areas.[29]

Neuromuscular coordination training can also induce the central and peripheral nervous systems adaptation because in this exercise repetitive movements are performed on flat and non-flat surfaces which provide repeated stimulation to joint mechanoreceptors so as to train neuromuscular function.[30] Neuromuscular training involves motor function and proprioceptive input with the aim of increasing muscle response and postural control. Neuromuscular training can significantly improve postural control by facilitating anticipatory postural adjustments. Repeated exposure to balance and stability disturbances on stable and unstable surfaces causes adaptations to motor unit recruitment. There is an increase in the sensitivity of afferent feedback pathways through neuromuscular training. In addition, neuromuscular training can stimulate proprioception by inducing peripheral and central nerve adaptations. The proprioceptive system, consisting of mechanoreceptors, provides information on joint position, kinaesthesia, and muscle tone. Peripheral adaptations that may occur in neuromuscular training most likely resulted from repeated stimulation of joint mechanoreceptors on stable and unstable surfaces. [31]

We also find that yoga training is not more effective than neuromuscular coordination training to improve gait speed, it was probably because yoga training in this study is a dynamic yoga training where each asana is maintained for a short time so that stretching and muscle contraction is not as optimal as static yoga training where each asana is maintained for a longer time. To be able to increase gait speed optimally, we recommend in future research to use a type of static yoga that combines various asanas that can specifically increase muscle strength and flexibility of the trunk, lower and lower extremities which can improve the movement of the hip, knee and ankle joints. We recommend for future research involving a larger sample size and yoga training should be combined with pranayama and meditation to achieve optimal increase in NGF levels.

The limitation of this study is the small number of samples and the intervention of yoga training is only in the form of asana training without pranayama and meditation. The combination of yoga training with pranayama and meditation is an exercise that can improve the health of overall brain activity through the activation of various brain waves, namely alpha, beta and theta waves so that it has the potential to induce neuroplasticity through increased production of various neurotrophic activities in the brain.

CONCLUSION

Yoga training is more effective than neuromuscular coordination exercise in improving the predictor parameters of fall risk, namely agility, visual reaction time and auditory reaction time. However, yoga training was not more effective than neuromuscular coordination exercise in improving gait speed and NGF levels. We suggest examining motor function and other biomarkers of nervous system adaptation in addition to the parameters studied in this study. We also recommend yoga training to be carried out in a comprehensive manner, namely a combination of asanas, pranayama and meditation. It is also necessary to carry out a specific biomechanical analysis for each asana so that the selection of the type of asana is more precise so as to provide optimal results in improving motor function and the nervous system adaptation.

AUTHOR CONTRIBUTION

NW: concepts, literature search, experimental studies, data acquisition, data analysis, statistical analysis, manuscript preparation; NA and IPGA: concept, manuscript review; LPRS and AWI: literature search, clinical studies, experimental studies, manuscript preparation, manuscript editing; GV: data acquisition, data analysis, statistical analysis.

CONFLICT OF INTEREST

The author reports no conflicts of interest in this work.

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