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Comparison of Dynamic Neuromuscular Stability Exercises and Corrective Exercises on Functional Movements, Respiratory Performance, Physical Fitness, and Mobility of Firefighters

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Abstract: *This study aimed to investigate the effects of dynamic neuromuscular stability exercises and corrective exercises on functional movements, respiratory performance, physical fitness, and mobility in firefighters. A semi-experimental study with a pre-test/post-test design was conducted, involving 75 volunteer firefighter athletes from Mashhad. Based on individual information and medical history questionnaires, participants had no record of severe injuries, were free from any illnesses, and met the criteria to participate in the study. The study sample was selected using accessible sampling methods. After completing informed consent forms, all participants were randomly divided into two groups—exercise and control—for assessment of the study variables using screening tests. The measured variables included dynamic neuromuscular stability using the Functional Movement Screen (FMS), the Davis Test, flexibility with a medicine ball throw, agility, respiratory rate, breath-holding, speed using the Schober Test, trunk flexor and extensor endurance, stair-step test, height, and weight. Participants in the exercise group underwent 8 weeks of training, 3 sessions per week, with each session lasting 45–60 minutes. Each session started with warm-up exercises and ended with cool-down exercises. At the end of the intervention period, all participants underwent post-tests under the same conditions as the pre-tests, and the collected data were analyzed. The Shapiro–Wilk test was used for data normality, and statistical analysis was performed using SPSS software ($p < 0.05$). The findings demonstrated that both dynamic neuromuscular stability exercises and corrective exercises had a significant impact on FMS scores ($p < 0.05$), respiratory performance ($p < 0.05$), and physical and motor tests in male firefighters ($p < 0.05$). Based on the findings and in line with previous research, the use of dynamic neuromuscular stability exercises and corrective exercises is recommended to improve functional movements, respiratory performance, physical fitness, and mobility in male firefighters.*

Keywords: *Firefighters, Dynamic Neuromuscular Stability, Corrective Exercises, Functional Movements, Respiratory Performance, Physical and movement fitness*

1. Introduction

Firefighting is a high-risk profession associated with alarming annual statistics of approximately 80,000 injuries and 100 fatalities. Firefighters are frequently exposed to toxic gases, hazardous combustion products, extreme heat, and intense radiation, coupled with demanding and strenuous working conditions. Notably, 45% of firefighter deaths are attributed to deficiencies in muscular capacity and endurance. Therefore, aerobic fitness, anaerobic capacity, muscular strength, and endurance are crucial components for their survival and effectiveness. However, many firefighters lack adequate physical fitness and struggle with excess weight, which leads to numerous musculoskeletal issues and movement dysfunctions. Enhancing firefighters' health and physical fitness not only improves their safety and well-being but also ensures their occupational readiness. Dynamic Neuromuscular Stabilization (DNS) exercises offer an effective and cost-efficient method for improving such fitness. These exercises optimize sensory-motor pathways by engaging the central nervous system, thereby preventing diseases and dysfunctions. By focusing on general movement patterns such as proper diaphragm activation, breathing patterns, and core stability, DNS creates a solid foundation for performing various movements (Bahiraei, 2023; Kaushik, 2024; Bae, 2002). DNS exercises enhance trunk stability by increasing intra-abdominal pressure through muscular contractions. Research has demonstrated their positive impact on physical health, which is especially significant given the role of posture and trunk strength in firefighting. A unique advantage of DNS exercises is their simultaneous focus on breathing mechanics and posture as interrelated factors. Consequently, DNS exercises improve trunk stability, alleviate spinal stress, and reduce movement dysfunctions and neuromuscular deficiencies (Kobesova et al., 2019). Moreover, implementing this training protocol requires minimal cost and specialist resources.

Corrective exercises, another category of physical activity, aim to improve structural anomalies and individuals' posture. Designing corrective exercise programs requires precise knowledge of an individual's anatomy and musculoskeletal structure, with the goal being optimal postural alignment. These exercises restore the body to its ideal state, creating conditions for improved functional performance. A noteworthy aspect of corrective exercises is the individualized definition of optimal posture, which varies across professions and activities. For example, military personnel, artists, manual laborers, athletes, students, and educators each have unique postural requirements based on their professional demands. For many individuals, good posture signifies comfort and balance under various conditions (Aktog et al., 2019; Bahiraei, 2023; Bahiraei, 2024). In ideal posture, joints are properly aligned, and muscles surround them in a balanced manner. Corrective exercises significantly enhance the quality of life for military personnel by reducing chronic lower back pain and enabling optimal functional performance. These exercises aim to facilitate pain-free physical activities by addressing muscular imbalances and compensatory movements, which are especially critical in firefighting due to structural anomalies and functional deficits that heighten injury risks in emergency situations (Osloner et al., 2021; Gutiérrez, 2023; Kang, 2024).

One key indicator of physical fitness and potential risks for injury is functional movement patterns. Functional movement capability refers to effective and precise execution of basic movement patterns and motor skills, requiring mobility, stability, coordination, and symmetry in foundational movements. According to Cook et al. (2014), functional movement screening (FMS) involves assessing seven basic movement patterns, where individuals need to exhibit sufficient stability and mobility to perform movements correctly. FMS is specifically designed to identify limitations and alterations in normal movement patterns while analyzing the interplay between the body's mobility and stability (Bogosovski et al., 2009; Afsari, 2024). These fundamental movement patterns are used to evaluate an individual's motor patterns and stability, with the test emphasizing the lower extremities, where weaknesses and imbalances are often most evident. Notably, even elite active individuals may exhibit deficiencies in executing these movement patterns. Failing to perform these movements leads to compensatory patterns that, when sustained, compromise biomechanical integrity and elevate risks for both minor and significant injuries (Landis et al., 2018). Implementing FMS exercises necessitates the integration of proprioception and kinesthetic sense in each component of the kinetic chain to create cohesive, optimized movement patterns (Lee et al., 2021). Maintaining physical fitness is vital for firefighters, as balance serves as one of the fundamental tasks of the neuromuscular system, playing a crucial role in both simple and complex activities. Impairments in balance are strongly correlated with an increased risk of injuries and falls during occupational tasks. Dynamic balance, essential for numerous functional activities, is particularly vulnerable to disturbances, making individuals prone to various injuries and impairments, as highlighted by Timothy (2016). Balance-disrupting factors in firefighting can be categorized into external factors such as uneven surfaces, which are linked to inadequate physical fitness, and internal factors, including physiological variables. Hence, physical fitness emerges as a critical priority for firefighters, guaranteeing the accomplishment of their objectives and missions.

To enhance firefighters' physical fitness, understanding their current status is essential. Cumming et al. (2018) emphasize that categorizing physical capabilities and implementing strategies to develop fitness levels require monitoring systems tailored to specific operational missions. Such systems can play an instrumental role in improving health and preventing irreversible injuries and diseases among firefighters (Chitlange, 2024; Baek et al., 2018; Taha, 2025). On a different note, Pavel Kolar advocates for assessing breathing patterns as the initial step in addressing functional dysfunctions within the human motor system. This recommendation stems from the stabilizing role of respiratory muscles and the significant influence of natural breathing mechanics on spinal alignment and stability (Sharma, 2024; Marinkovic, 2024). Elements of stability and movement control in sports also positively affect functional mobility (Mahdieh et al., 2020). Recent studies have increasingly explored the effects of exercise and physical activity-based interventions on functional mobility, primarily focusing on athletes, firefighters, military personnel, and other specialized professional populations. Promising results indicate improvements in motor abilities and reductions in injury risks through such interventions. For instance, several studies have demonstrated that exercise intervention programs can enhance FMS composite scores in athletes, firefighters, and military personnel while reducing asymmetrical patterns and injury risks (Kiesel et al., 2017; Dinc et al., 2017; Ulusoy, 2025). A recent meta-analysis further confirmed that corrective functional exercises can improve FMS composite scores, enhance movement patterns, and mitigate sports-related injuries (Chen et al., 2021). Nonetheless, despite existing research on the impact of exercise interventions on functional mobility among trained individuals, conclusive findings remain elusive due to variability in sample sizes, study designs, and intervention programs.

Respiratory function is one of the most critical indicators among firefighters. This group, facing harsh and demanding conditions, requires optimal respiratory functionality to prevent complications. In recent years, factors such as increased tobacco use, lifestyle changes, environmental pollution, and exposure to occupational hazards have contributed to a rise in pulmonary diseases. From an occupational health perspective, the respiratory system is one of the most vital systems of the human body, yet it remains susceptible to numerous adverse effects and disorders. This concern is particularly pronounced in professions such as firefighting (Ogunkoya et al., 2021; Hu, 2025). Occupational respiratory disorders and symptoms may result from repeated or prolonged exposure to hazardous chemicals, vapors, or toxic gases. Research indicates that respiratory diseases account for approximately 20% of primary healthcare visits and are the second leading cause of hospital admissions (Graham et al., 2021). Within this context, the optimal condition of the diaphragm and core muscles holds significant importance. Studies have shown that insufficient coordination of the diaphragm and other core muscles may threaten lumbar spine stability and lead to impaired movement function in the region. Emphasis is predominantly placed on the importance of correct posture and its influence on respiratory performance capabilities, as mechanical and neuromuscular control of posture are interconnected.

Weakness or dysfunction of the diaphragm, which is the primary respiratory muscle and one of the key muscles within the central body region, can negatively affect other structures. Research highlights a positive correlation between diaphragm dysfunction, poor breathing patterns, and deficits in motor tasks. Findings suggest that diaphragm weakness or dysfunction, combined with inadequate coordination with other central muscles, may lead to reduced muscular stability, impaired motor patterns, and consequently, a decline in movement abilities. Respiratory dysfunction, as part of the human movement system, can result in decreased muscle efficiency, disruption in homeostasis, threats to individual health, and impacts on various aspects of quality of life. Moreover, the multitasking nature of breathing may be affected by musculoskeletal disorders, chronic stress, or factors such as restricted chest wall expansion. Obesity plays a significant role in causing inflammation in various parts of the body, including the respiratory tract (Cerami et al., 2019). Studies have indicated that obesity can result in reduced lung function, particularly decreasing Forced Vital Capacity (FVC) and Forced Expiratory Volume in the first second (FEV1), which have been identified as dangerous factors affecting respiratory efficiency (Rabieezadeh, 2024; Vasileva, 2025). These reductions in expiratory lung volumes may contribute to dysfunction in the mechanical performance of the airways and neuromuscular control (Canli, 2025; Afsari, 2024; Chitlange, 2024). Furthermore, increased breathing depth caused by the phenomenon of overweight and obesity has been observed in affected individuals (Zhang, 2025; Taha, 2024). Firefighters, categorized as one of the most hazardous and demanding occupational groups, must possess high physical and motor abilities to perform optimally during emergency situations. One of the critical components for their success lies in appropriate motor and respiratory performance, both of which are closely tied to neuromuscular stability and physical fitness.

Given the challenging and severe conditions firefighters face, it is essential to identify and explore effective training methods aimed at improving these key aspects. In recent years, dynamic neuromuscular stability (DNS) training has emerged as a novel approach for improving motor and respiratory performance in various athletic populations. These types of training focus on enhancing motor control and coordination between muscles, leading to improved stability and reduced injury risk. On the other hand, corrective exercises—designed to rectify dysfunctional movement patterns and optimize respiratory performance—have also gained significant attention among researchers. Despite this, there are limited systematic comparisons regarding the effects of these two training approaches on firefighters’ functional movements, respiratory performance, and physical fitness.

This gap necessitates research investigating and comparing the effects of these two approaches on improving the physical and motor condition of firefighters, ultimately identifying the most effective training method for increasing performance and minimizing injury risks. This study, therefore, aims to address the following research questions:

1. What differences exist in the effects of dynamic neuromuscular stability training and corrective exercises on firefighters' functional movement?
2. How do these two training approaches impact firefighters' respiratory function and physical fitness?
3. Which training method leads to greater improvements in firefighters' functional and respiratory performance?

1.1. Research Background

Manakosh (2025) states that individuals with intellectual disabilities (ID) often exhibit lower levels of physical fitness compared to the general population. Dynamic Neuromuscular Stabilization (DNS) training has been suggested as a potential method for improving motor function and physical fitness in individuals with ID. A randomized controlled trial explored the effects of an 8-week DNS training program on strength, endurance, and flexibility among adults with ID. The findings revealed significant improvements in the DNS group compared to the control group, and these improvements were maintained during the 3-month follow-up. This study highlights the potential of DNS training in promoting fitness and well-being in individuals with ID. Med (2025) reported in an article that a study involving 32 participants (16 in the experimental group and 16 in the control group) revealed that both groups showed post-treatment improvements in the Visual Analog Scale (VAS), Oswestry Disability Index (ODI) - Chinese version, Pain Self-Efficacy Questionnaire (PSEQ), joint mobility, maximum isometric strength, muscular endurance of the abdominal pressure, transverse abdominal muscles, and multifidus muscle metrics. However, the experimental group exhibited significantly greater improvements than the control group. These findings indicate that Dynamic Neuromuscular Stabilization (DNS) technology combined with Kinesio Taping can significantly improve neuromuscular function, increase pain self-efficacy, reduce discomfort, and enhance functional outcomes in patients with non-specific chronic low back pain.

Sel (2025) investigated challenges arising from ill-fitting occupational clothing and equipment for female firefighters. The research revealed that most personal protective equipment (PPE) and firefighting gear are designed to accommodate male physiques, resulting in various issues for female firefighters. These challenges include increased exposure to hazardous materials, difficulty regulating body temperature, heightened risk of injury due to compensatory movements, and reduced confidence and mental health. This article offers recommendations for sports professionals to address these issues by designing programs focused on joint-specific stabilization, reducing health risk factors, and collaborating with certified experts to create suitable programs. The paper emphasizes the need for further research and provides valuable insights into mitigating injury risks and tailoring exercise considerations for female firefighters, taking into account the limitations of improperly designed equipment. Mahdieh et al. (2022) conducted a study to evaluate the impact of DNS training on functional movement patterns. This study examined whether a system of fundamental motor exercises known as DNS could improve functional movement patterns. Thirty-two female students were randomly divided into two groups to receive either DNS exercises or general physical fitness training. Both groups engaged in 15-minute training sessions, three times per week, for six weeks. The effectiveness of the training was assessed using five functional movement tests before and after the intervention. Findings demonstrated that the DNS group achieved greater rates of improvement compared to the general fitness training group. The highest and lowest differences in progress between the groups, as determined by Eta-square coefficients, were observed in the functional balance screening test (7 points). The results supported the hypothesis that DNS exercises could be effectively used to enhance functional movement patterns (Mahdieh et al., 2020).

Skotnicka et al. (2017) investigated the movement chain model within the human motor system, specifically highlighting the interconnected and interdependent relationship between proximal and distal parts of the system in motor tasks. They emphasized the central role of the body's core in providing chain stability during functional activities. The study identified core stability deficits, imbalances, and asymmetrical muscle weaknesses in foundational motor patterns as significant contributing factors to physical impairments and movement disorders. Additionally, they introduced a tool based on preventative strategies aimed at assessing the effectiveness of corrective and core stability training on improving foundational motor patterns in students. The quality of participants' motor patterns was evaluated using the Functional Movement Screen (FMS). Researchers concluded that implementing such exercises could serve as a starting point for designing programs to prevent physical and motor impairments (Skotnicka et al., 2017). Davidek et al. (2017) examined the effects of a 6-week dynamic neuromuscular stability training program on the maximum paddle force in kayak athletes. The training included activities in quadruped position, side sitting, and squatting, performed after each standardized training session during the athletic season. Results indicated significant improvements in maximum paddle force in the experimental group, whereas no such improvements were observed in the control group (Davidek & Andel, 2018). Szijia et al. (2017) conducted a study aimed at evaluating the influence of deep stabilizer muscle activity on posture control and the quality of respiratory movements. Sagittal and frontal posture alignments were assessed using photogrammetry. The results showed significant changes in sagittal posture alignment and increased breadth and depth of respiratory movements following the intervention. However, the study primarily focused on the biomechanical aspect of breathing and did not evaluate pulmonary and respiratory performance. Further research exploring the effects of deep stabilizer muscle exercises on pulmonary function has been suggested (Szczygiet et al., 2017). Miketa et al. (2017) explored the relationship between breathing exercises and the enhancement of postural stability in healthy young individuals. They examined the effects of 15 breathing training sessions, each lasting 10 minutes, performed three times per week. The study revealed that three weekly sessions of breathing exercises reduced compensatory and uncoordinated contractions during activities requiring stability, consequently improving postural stability and intra-abdominal pressure. Furthermore, increased awareness of proper utilization of all abdominal muscles involved in intra-abdominal pressure reduced pre-existing compensatory movement patterns and enhanced postural stability (Miketa et al., 2017).

2. METHODOLOGY

This study was an applied and quasi-experimental research conducted on 75 firefighters in Mashhad city. The participants were randomly assigned to two groups: 25 in the training group and 25 in the control group. The independent variables of the study included dynamic neuromuscular stability (DNS) exercises and corrective training, while the dependent variables consisted of functional movements, respiratory performance, physical fitness, and motor abilities of the firefighters. Prior to the intervention, the participants were informed about the objectives and methodology of the study, and written consent was obtained from them. Personal information, including age, height, weight, and body mass index (BMI), was measured. Forty-eight hours before the interventions, pre-tests were conducted to evaluate physical and motor fitness factors as well as the quality of functional movements. The training group performed DNS neuromuscular stability exercises for eight weeks, three sessions per week, with each session lasting 45–60 minutes, while the control group did not engage in any specific activities during this period and continued their daily routines. Forty-eight hours after the completion of the interventions, post-tests were conducted to remeasure the variables under investigation. The training protocol included warm-up and cool-down sessions, and all tests were conducted at the same time of the day to ensure the accuracy of the results. The following variables were measured during the pre-test and post-test phases:

2.1. Body Composition Measurements

- **Weight:** Measured using a digital scale manufactured in Germany.
- **Body Composition:** Determined using Harpenden Skinfold Caliper RH159B (manufactured in the UK). Body density was calculated using the Jackson and Pollock equation, and body fat percentage was calculated using Siri's equation.
- **Waist Circumference:** Measured at the narrowest point.
- **Hip Circumference:** Measured at the most prominent point.
- **Chest Circumference:** Measured in two positions:
- Upper chest: At maximum inspiration and expiration at the level of the axilla.
- Lower chest: At maximum inspiration and expiration at the level of the sternum.
- **Abdominal Circumference:** Measured at the level of the navel in two positions: maximum inspiration and maximum expiration.

2.2. Cardiopulmonary Measurements

- **Resting Heart Rate:** Recorded in a supine position for 15 seconds. Measurements were performed three times daily.
- **Respiratory Rate:** Measured in a seated position by counting the number of breaths in one minute based on shoulder and chest movements. Abnormal rates were defined as equal to or greater than 16 breaths/min, while normal rates were less than 16 breaths/min.
- **Breath-Holding Test:** Measured the time of breath-holding after exhaling and inhaling. Abnormal values were defined as less than 25 seconds, while normal values were equal to or greater than 25 seconds.

2.3. Physical Fitness and Motor Ability Tests

- **Speed:** Assessed using a 30-meter sprint test. The fastest time from two runs was recorded for analysis.
- **Agility:** Evaluated using the Illinois Agility Test on a rectangular field measuring 10 × 5 meters. Participants ran at maximum speed toward the obstacles, and the best record from three trials was recorded.
- **Explosive Power:** Measured using a vertical jump test. Participants stood next to a scaled wall, marked their maximum reach height, and performed vertical jumps. The highest point touched during the jump was recorded. Three trials were conducted, and the best score was taken.
- **Landing Error Scoring System (LESS):** Used to assess improper landing patterns. Participants stood on a 30-cm box, jumped forward, and attempted to land beyond the target line with both feet. This test was performed three times, and the LESS score was recorded to identify errors.
- **Flexibility:** Measured using the sit-and-reach test.

2.4. Balance Measurements

- **Static Balance:** Assessed by standing on one leg with eyes closed and hands placed on the hips. The time spent maintaining balance was recorded.
- **Dynamic Balance:** Measured in three directions: anterior-posterior, medial-lateral, and posterior-external. The participants' ability to maintain balance without errors was scored.

2.5. Functional Movement Assessments

- **Functional Movement Screen (FMS):** Comprised seven movement tests designed to assess mobility and stability. Scoring was based on the quality of movements performed, ranging from the presence of pain (low scores) to perfect performance (maximum score of 21).
- **Single-Leg Squat Test:** Conducted following the method of Yugalde et al., evaluating eight errors: hand release, Trendelenburg sign, valgus collapse of the stance leg, hip flexion, trunk rotation and bending, and knee instability. Higher scores indicated more errors.
- **Upper Limb Stability and Agility Test (Davis Test):** Participants rapidly alternated touching two horizontal bars with their left and right hands. Results from three trials were recorded.

2.6. Aerobic Capacity

- **Harvard Step Test:** Evaluated aerobic capacity using a 51-cm step. Participants performed stepping at a rate of 30 steps per minute for 5 minutes. Heart rate was recorded three times after the test at specific intervals.

2.7. Muscle Endurance Tests

- **Endurance of Trunk Flexor Muscles:** Participants maintained a position at a 60-degree angle with the ground for as long as possible. Duration was recorded in seconds.
- **Endurance of Trunk Extensor Muscles:** Participants held their torso off the chest in a specific position for the maximum possible duration. The time from lifting off the chair until returning to contact was recorded.

3. Data Analysis Method

The data were described using mean and standard deviation. Normal distribution of the data was assessed using the Kolmogorov-Smirnov test, and homogeneity of variances was confirmed with Levene's test. Variable changes were examined using mixed analysis of variance (ANOVA), and if necessary, analysis of covariance (ANCOVA). The significance level was set at 0.05, and all calculations were performed using SPSS software version 19.

3.1. Data Analysis

The mean and standard deviation of the participants' data for each group are presented in Table 1.

Table 1. *Participant Characteristics*

Variable	Group	Mean ± SD
Age (years)	DNS	36.7 ± 2.9
	Corrective	33.8 ± 3.2
	Control	33.5 ± 1.2
Height (cm)	DNS	177.8 ± 7.5
	Corrective	178.6 ± 5.3
	Control	178.7 ± 5.3
Weight (kg)	DNS	81.6 ± 11.9
	Corrective	82.2 ± 7.9
	Control	82.2 ± 8.7
BMI (kg/m²)	DNS	25.7 ± 2.9
	Corrective	25.7 ± 1.8
	Control	25.7 ± 2.1
Body Fat Percentage (kg/m²)	DNS	22.5 ± 4.3
	Corrective	21.7 ± 2.9
	Control	20.9 ± 3.2

These data summarize the mean and standard deviation of variables such as age, height, weight, BMI, and body fat percentage for the DNS group, corrective group, and control group. The mean age in the corrective group (33.8 years) is slightly higher than in the control group (33.5 years) and DNS group (36.7 years). The standard deviation for the control group (2.1) is significantly lower than the other two groups, indicating less variability in age within this group. The mean height across all three groups is approximately similar, around 177–178 cm. The standard deviation for the DNS group is the highest, indicating greater variability in height within this group. The mean weight in the DNS and corrective groups is almost identical (approximately 82 kg), while the control group has slightly lower weight (82 kg). The standard deviation for the DNS group is the highest. The mean BMI across all three groups is approximately similar (around 25). The standard deviation is relatively high in all groups, indicating variability in BMI values within each group. The mean body fat percentage in the control group (20.9%) is lower than in the DNS (22.5%) and corrective groups (21.7%). The standard deviation in the DNS group is the highest.

3.2. Assessment of Normal Distribution of Data

To ensure the normality of data distribution before employing appropriate statistical methods and testing the research hypotheses, the Shapiro-Wilk test was utilized. The results are shown in Tables 2 through 6.

Table 2-4. *Shapiro-Wilk Test Results for Body Composition Indicators*

Variable	Group	Z-score	P-value	Result
Body Weight	DNS	0.956	0.346	No
	Corrective	0.567	0.967	No
	Control	0.445	0.961	No
BMI	DNS	0.937	0.126	No
	Corrective	0.973	0.71	No
	Control	0.965	0.523	No
Body Fat Percentage	DNS	0.946	0.2	No
	Corrective	0.971	0.681	No
	Control	0.965	0.523	No

The significance level was set at 0.05. Based on the calculated Z-scores and P-values, none of the variables, including body weight, BMI, and body fat percentage, showed significant differences between the DNS, corrective, and control groups. This result may indicate similarities among these groups or that the specific interventions or training applied to each group did not have a significant effect on these variables.

Table 3. *Shapiro-Wilk Test Results for Physical Fitness Indicators*

Variable	Group	Z-score	P-value	Result
OTT Test - Flexion	DNS	0.924	0.062	No
	Corrective	0.925	0.067	No
	Control	0.889	0.052	No
OTT Test - Extension	DNS	0.809	0.061	No
	Corrective	0.842	0.065	No
	Control	0.878	0.126	No
OTT Test - Flexion	DNS	0.963	0.467	No
	Corrective	0.951	0.261	No
	Control	0.863	0.503	No
OTT Test - Extension	DNS	0.927	0.073	No
	Corrective	0.842	0.120	No
	Control	0.916	0.061	No

Overall, data analysis reveals that none of the observed differences in Schober and Out tests (both flexion and extension) between the DNS, corrective, and control groups are statistically significant. Particularly in the Out test, all P-values exceed 0.05, except in some cases nearing the significance threshold in the Schober test. Table 3 indicates that the data distribution for all physical fitness variables in all three groups is normal. Therefore, parametric tests such as repeated measures ANOVA can be used for hypothesis testing and data analysis.

Table 4. *Shapiro-Wilk Test Results for Motor Performance Indicators*

Variable	Group	Z-score	P-value	Result
Medicine Ball Throw	DNS	0.935	0.116	No
	Corrective	0.967	0.572	No
	Control	0.938	0.133	No
Davis Test	DNS	0.803	0.103	No
	Corrective	0.963	0.486	No
	Control	0.934	0.109	No
Single-Leg Squat	DNS	0.845	0.201	No
	Corrective	0.870	0.066	No
	Control	0.912	0.071	No
Y-Balance Test	DNS	0.976	0.784	No
	Corrective	0.961	0.437	No
	Control	0.970	0.648	No
Vertical Jump	DNS	0.985	0.966	No
	Corrective	0.943	0.169	No
	Control	0.955	0.325	No
Agility	DNS	0.920	0.052	No
	Corrective	0.955	0.323	No
	Control	0.959	0.399	No
Static Balance	DNS	0.907	0.062	No
	Corrective	0.945	0.191	No
	Control	0.968	0.585	No

As seen in Table 4, the data distribution for all motor performance indicators is normal in all three groups.

Table 5. *Shapiro-Wilk Test Results for Respiratory Performance Indicators*

Variable	Group	Z-score	P-value	Result
Respiratory Rate	DNS	-	0.161	No
	Corrective	0.958	0.369	No
	Control	0.947	0.214	No
Breath Holding (after)	DNS	0.966	0.545	No
	Corrective	0.956	0.346	No
	Control	0.99	0.996	No
Breath Holding (after)	DNS	0.96	0.416	No
	Corrective	0.952	0.281	No
	Control	-	0.445	No
Abdominal Circumference (Rest)	DNS	0.953	0.287	No
	Corrective	0.969	0.617	No

	Control	0.952	0.285	No
Abdominal Circumference (Inhalation)	DNS	0.969	0.628	No
	Corrective	0.971	0.682	No
	Control	0.967	0.578	No
Abdominal Circumference (Exhalation)	DNS	0.944	0.182	No
	Corrective	0.982	0.916	No
	Control	0.946	0.201	No
Chest Circumference (Rest)	DNS	0.95	0.248	No
	Corrective	0.947	0.213	No
	Control	0.966	0.555	No
Chest Circumference (Inhalation)	DNS	0.938	0.136	No
	Corrective	0.961	0.428	No
	Control	0.963	-	No

* The significance level was considered as $P < 0.05$.

As shown in Table 5, the data distribution for all variables related to respiratory performance is normal. Thus, parametric tests can be used for hypothesis testing and data analysis.

Table 6. *Shapiro-Wilk Test Results for Functional Movement Screen (FMS) Tests*

Variable	Group	Z-score	P-value
Deep Squat	DNS	0.590	0.000
	Corrective	0.742	0.000
	Control	0.308	0.000
Stepping Over Obstacle (Right)	DNS	0.766	0.000
	Corrective	0.744	0.000
	Control	0.520	0.000
Stepping Over Obstacle (Left)	DNS	0.565	0.000
	Corrective	0.445	0.000
	Control	1.384	0.000
Lunge (Right)	DNS	0.679	0.000
	Corrective	0.744	0.000
	Control	0.709	0.000
Lunge (Left)	DNS	0.766	0.000
	Corrective	0.721	0.000
	Control	0.728	0.000
Shoulder Mobility (Right)	DNS	0.789	0.000
	Corrective	0.547	0.000
	Control	0.392	0.000
Shoulder Mobility (Left)	DNS	0.691	0.000
	Corrective	0.566	0.000
	Control	0.618	0.000
Active Straight Leg Raise (Right)	DNS	0.786	0.000
	Corrective	0.764	0.000
	Control	0.784	0.000
Active Straight Leg Raise (Left)	DNS	0.676	0.000
	Corrective	0.701	0.000
	Control	0.668	0.000
Trunk Stability Push-Up	DNS	0.771	0.000
	Corrective	0.847	0.002
	Control	0.785	0.000
Rotational Stability (Right)	DNS	0.625	0.000
	Corrective	0.729	0.000
	Control	0.639	0.000
Rotational Stability (Left)	DNS	1.693	0.000
	Corrective	0.625	0.000
	Control	0.728	0.000
Total Score	DNS	0.978	0.840
	Corrective	0.870	0.004
	Control	0.961	0.427

Table 6 demonstrates that the data distribution for all FMS tests is non-normal. Thus, non-parametric tests must be utilized for hypothesis testing.

3.3. 3-4 Hypothesis Testing

Null Hypothesis 1: There is no significant difference in the effects of eight weeks of dynamic neuromuscular stability exercises and corrective training on FMS tests in male firefighters (P > 0.05).

Table 7. *Intragroup and Intergroup Changes in Screening Tests of Motor Performance*

Variable	Groups	Pre-test M(SD)	Post-test M(SD)	Intragroup Changes	Intergroup Changes
Deep Squat	DNS	1.68 (0.48)	*2.52 (0.51)*	<0.001	<0.001
	Corrective	2.08 (0.57)	1.84 (0.47)	0.058	
	Control	1.92 (0.28)	1.88 (0.72)	0.763	
Stepping Over Obstacle (Right)	DNS	1.68 (0.63)	*2.24 (0.43)*	<0.001	0.001
	Corrective	1.80 (0.58)	1.56 (0.58)	0.083	
	Control	1.76 (0.52)	1.88 (0.66)	0.405	
Stepping Over Obstacle (Left)	DNS	1.72 (0.46)	*2.40 (0.50)*	<0.001	<0.001
	Corrective	1.84 (0.37)	# 1.44 (0.51)	0.002	
	Control	1.88 (0.33)	1.88 (0.33)	1	
Lunge (Right)	DNS	1.44 (0.65)	*2.24 (0.43)*	<0.001	<0.001
	Corrective	1.56 (0.65)	# 1.20 (0.41)	0.003	
	Control	1.28 (0.54)	1.76 (0.52)	0.007	
Lunge (Left)	DNS	1.68 (0.63)	*2.12 (0.33)*	<0.0001	<0.001
	Corrective	1.52 (0.58)	# 1.20 (0.41)	0.005	
	Control	1.44 (0.58)	1.64 (0.49)	0.059	
Shoulder Mobility (Right)	DNS	2.00 (0.64)	*2.52 (0.51)*	<0.001	<0.001
	Corrective	1.92 (0.40)	1.84 (0.47)	0.48	
	Control	1.84 (0.47)	1.72 (0.46)	0.257	
Shoulder Mobility (Left)	DNS	1.76 (0.52)	*2.24 (0.43)*	<0.001	0.001
	Corrective	2.00 (0.41)	1.84 (0.37)	0.046	
	Control	1.92 (0.57)	1.88 (0.33)	0.705	
Active Leg Raise (Right)	DNS	1.92 (0.64)	*2.52 (0.51)*	<0.001	0.016
	Corrective	2.28 (0.61)	2.08 (0.49)	0.059	
	Control	2.20 (0.64)	2.12 (0.66)	0.527	
Active Leg Raise (Left)	DNS	2.00 (0.50)	*2.24 (0.43)*	0.014	0.014
	Corrective	2.12 (0.52)	1.84 (0.47)	0.02	
	Control	2.08 (0.49)	2.12 (0.52)	0.705	
Trunk Stability Push-Up	DNS	1.48 (0.82)	*2.40 (0.58)*	<0.001	<0.001
	Corrective	1.28 (0.74)	1.44 (0.58)	0.102	
	Control	1.28 (0.68)	1.64 (0.70)	0.039	
Rotary Stability (Right)	DNS	1.40 (0.50)	*2.04 (0.20)*	<0.001	<0.001
	Corrective	1.36 (0.57)	# 1.40 (0.50)	0.705	
	Control	1.52 (0.51)	1.68 (0.56)	0.157	
Rotary Stability (Left)	DNS	1.44 (0.58)	*1.96 (0.35)*	<0.001	<0.001
	Corrective	1.60 (0.50)	# 1.08 (0.28)	<0.001	
	Control	1.44 (0.58)	1.48 (0.58)	0.705	
Total Score	DNS	10.60 (2.12)	*15.52 (1.56)*	<0.001	<0.001
	Corrective	11.52 (2.74)	# 10.16 (2.01)	0.001	
	Control	12.64 (2.01)	11.76 (2.82)	0.036	

* Significant difference compared to the Corrective group.

Significant difference compared to the Control group.

Table 7. Intra-Group and Inter-Group Changes in Functional Movement Screening Tests Results of the non-parametric Kruskal-Wallis test indicate that for all seven FMS tests and the total FMS score, there are significant differences between the groups. Thus, the null hypothesis is rejected. Pairwise comparisons using the non-parametric Mann-Whitney test show significant differences between the DNS training group and the other two groups. Additionally, significant differences were observed between the corrective training and control groups in certain variables such as hurdle step (left), lunge (left and right), rotational stability (left and right), and total score. Overall, the DNS group

demonstrated significant positive changes in all tests (e.g., deep squat, hurdle step, lunge, shoulder mobility, and rotational stability). P-values below 0.001 clearly indicate that this group showed significant improvements compared to the other two groups. The corrective and control groups generally showed no significant changes, which may suggest that their interventions or training programs did not significantly improve performance. These findings emphasize that specific movement-based programs like DNS can lead to substantial improvements in physical performance.

Hypothesis 2: There is no significant difference in the effects of eight weeks of dynamic neuromuscular stability exercises and corrective training on respiratory performance in male firefighters (P > 0.05).

Table 8. *Intra-Group and Inter-Group Changes in Respiratory Performance Tests*

Variables	Groups	Pre-Test M (SD)	Post-Test M (SD)	Time Effect	Time × Group Effect
Respiratory Rate	DNS	18.32 (2.67)	16.04 (1.77)	<0.001	<0.001
	Corrective	15.44 (1.80)	18.12 (1.74)		
	Control	15.44 (1.50)	17.36 (1.91)		
Breath-Holding After Inhalation	DNS	45.08 (12.61)	58.00 (9.11)	<0.001	<0.001
	Corrective	52.92 (9.25)	53.45 (8.59)		
	Control	53.85 (7.51)	54.43 (7.32)		
Breath-Holding After Exhalation	DNS	17.93 (6.64)	21.67 (4.43)	0.001	<0.001
	Corrective	18.34 (3.58)	18.31 (3.20)		
	Control	20.00 (3.76)	19.00 (3.04)		
Abdominal Circumference (Resting State)	DNS	91.38 (7.12)	90.26 (6.59)	0.085	0.012
	Corrective	91.34 (5.87)	91.18 (6.97)		
	Control	90.98 (5.35)	91.26 (5.61)		
Abdominal Circumference (Inhalation)	DNS	93.54 (7.96)	95.38 (6.58)	0.002	0.002
	Corrective	94.58 (6.03)	94.46 (6.61)		
	Control	95.38 (5.38)	95.80 (5.55)		
Abdominal Circumference (Exhalation)	DNS	88.44 (7.16)	85.64 (6.64)	<0.001	<0.001
	Corrective	88.94 (6.11)	88.84 (6.91)		
	Control	88.44 (5.69)	88.22 (5.73)		
Thoracic Circumference - Sternum Area (Resting State)	DNS	94.78 (6.67)	94.66 (6.62)	0.655	0.543
	Corrective	92.48 (5.95)	92.50 (6.01)		
	Control	92.96 (5.11)	92.98 (4.95)		
Thoracic Circumference - Sternum Area (Inhalation)	DNS	97.48 (6.30)	97.90 (6.94)	0.013	0.560
	Corrective	95.12 (6.21)	95.28 (5.98)		
	Control	94.80 (5.11)	95.34 (5.02)		
Thoracic Circumference - Sternum Area (Exhalation)	DNS	92.54 (6.91)	92.00 (6.93)	0.004	0.001
	Corrective	90.84 (6.49)	91.08 (6.26)		
	Control	92.00 (5.04)	91.40 (5.09)		
Thoracic Circumference - Axilla Area (Resting State)	DNS	102.06 (8.32)	102.12 (8.07)	0.581	0.921
	Corrective	102.20 (5.67)	102.16 (5.59)		
	Control	101.94 (6.48)	101.98 (6.04)		
Thoracic Circumference - Axilla Area (Inhalation)	DNS	104.50 (7.42)	106.36 (7.41)	0.679	0.249
	Corrective	105.13 (5.75)	105.16 (6.07)		
	Control	104.50 (6.60)	100.94 (19.60)		
Thoracic Circumference - Axilla Area (Exhalation)	DNS	99.10 (7.51)	93.30 (7.53)	0.002	0.016
	Corrective	99.82 (5.86)	99.88 (5.79)		
	Control	100.36 (6.42)	99.94 (6.16)		

In most variables, particularly in the breath-holding tests and abdominal circumference during exhalation, the DNS group demonstrated significant improvements. This indicates that the interventions implemented in this group had a notable and considerable positive impact on respiratory performance. However, in some variables (e.g., thoracic circumference), no significant differences were observed between the groups. The results of the repeated measures ANOVA showed that there were significant differences between the effects of eight weeks of dynamic neuromuscular stability (DNS) exercises and corrective training on the tests for respiratory rate, breath-holding after inhalation and exhalation, abdominal circumference (resting state, inhalation, and exhalation), thoracic circumference - sternum area (exhalation), and thoracic circumference - axilla area (exhalation).

Hypothesis 3: There is no significant difference between the effects of eight weeks of dynamic neuromuscular stability (DNS) exercises and corrective training on physical and motor fitness tests in male firefighters (P > 0.05).

Table 9. *Within-Group and Between-Group Changes in Motor Fitness Factors*

Variable	Groups	Pre-Test M (SD)	Post-Test M (SD)	Time Effect	Time × Group Effect
Medicine Ball Throw	DNS	5.18 (0.79)	6.16 (0.88)	<0.001	<0.001
	Corrective	5.61 (0.84)	5.62 (0.81)		
	Control	5.95 (0.83)	5.94 (0.83)		
200m Test	DNS	16.92 (6.43)	#*21.64 (5.73)	<0.001	<0.001
	Corrective	15.08 (2.55)	14.96 (2.54)		
	Control	13.92 (2.06)	13.44 (1.08)		
Left Single-Leg Squat	DNS	3.00 (0.91)	#*1.20 (0.64)	<0.001	<0.001
	Corrective	3.00 (1.19)	3.24 (0.92)		
	Control	2.88 (0.78)	3.00 (0.71)		
Right Single-Leg Squat	DNS	3.12 (1.01)	#*1.20 (0.58)	<0.001	<0.001
	Corrective	3.20 (0.96)	3.40 (0.87)		
	Control	3.24 (0.97)	3.16 (0.69)		
Left Y-Balance Test	DNS	89.80 (10.88)	#*101.36 (10.21)	<0.001	<0.001
	Corrective	82.45 (7.75)	82.19 (8.32)		
	Control	87.36 (8.44)	86.07 (9.02)		
Right Y-Balance Test	DNS	91.02 (10.99)	#*103.06 (9.88)	<0.001	<0.001
	Corrective	83.63 (7.63)	82.18 (7.43)		
	Control	87.24 (7.68)	86.35 (8.17)		
Vertical Jump	DNS	39.30 (8.31)	43.72 (8.55)	<0.001	<0.001
	Corrective	40.92 (5.68)	40.20 (5.60)		
	Control	42.48 (5.22)	42.52 (5.27)		
Agility	DNS	20.25 (1.71)	#*19.22 (1.62)	0.005	<0.001
	Corrective	20.58 (1.96)	21.15 (1.54)		
	Control	21.41 (1.58)	21.01 (1.39)		
Static Balance	DNS	2.27 (0.87)	#*4.10 (0.85)	<0.001	<0.001
	Corrective	2.47 (0.78)	2.29 (0.69)		
	Control	2.29 (0.56)	2.25 (0.43)		

* Significant difference compared to the Corrective group.

Significant difference compared to the Control group.

In this analysis, no significant differences were observed in the changes in physical and motor fitness tests between the DNS, Corrective, and Control groups. This finding indicates that the effects of eight weeks of dynamic neuromuscular stability training and corrective exercises do not differ in the tests under investigation.

Table 10. *Within-Group and Between-Group Changes in Physical Fitness Factors*

Variable	Groups	Pre-Test M (SD)	Post-Test M (SD)	Time Effect	Time × Group Effect
Flexion - Schober Test	DNS	15.18 (1.04)	#*16.02 (0.53)	0.616	<0.001
	Corrective	14.64 (1.20)	14.12 (0.78)		
	Control	14.22 (0.92)	14.02 (0.70)		
Extension	DNS	7.20 (2.01)	#*6.22 (0.96)	0.258	0.001
	Corrective	7.80 (0.46)	8.08 (0.34)		

	Control	7.98 (0.60)	8.24 (0.56)		
Flexion - Sit-and-Reach	DNS	32.04 (1.21)	33.84 (0.76)	<0.001	<0.001
	Corrective	32.64 (0.76)	32.36 (0.62)		
	Control	32.70 (0.85)	32.76 (0.66)		
Extension	DNS	27.84 (1.01)	#*26.62 (0.74)	<0.001	<0.001
	Corrective	27.72 (0.72)	27.96 (0.38)		
	Control	27.94 (0.53)	27.82 (0.48)		
Flexibility	DNS	36.22 (8.35)	*42.08 (7.44)	<0.001	<0.001
	Corrective	40.28 (7.13)	40.16 (6.93)		
	Control	44.42 (6.10)	44.09 (5.29)		
Extensor Endurance	DNS	78.29 (35.16)	#*94.31 (33.24)	<0.001	<0.001
	Corrective	61.67 (18.57)	61.80 (18.44)		
	Control	62.75 (22.88)	62.83 (21.05)		
Flexor Endurance	DNS	52.20 (22.00)	64.29 (17.17)	<0.001	<0.001
	Corrective	54.70 (10.77)	54.17 (11.72)		
	Control	56.98 (13.74)	56.18 (12.17)		

* Significant difference compared to the Corrective group.

Significant difference compared to the Control group.

The results indicate that only the DNS group demonstrated significant improvements in various physical fitness tests (flexion and extension) as well as in extensor and flexor endurance. In other words, the exercises performed in the DNS group had a positive effect, while the Corrective and Control groups did not show any significant changes. The time effect indicates within-group changes that were notable in the DNS group, while the time × group interaction effect suggests no specific differences between groups in the observed changes. These findings suggest that the specific exercises performed in the DNS group were distinctly effective, though they did not result in a significant advantage compared to the other groups. Furthermore, the study demonstrates that Corrective and Control exercises failed to produce significant improvements in the physical fitness factors under investigation. The repeated-measures analysis results (Tables 9 and 10) show that there is a significant difference in the effects of eight weeks of Dynamic Neuromuscular Stability (DNS) training and Corrective exercises on physical and motor fitness tests in male firefighters; thus, the null hypothesis was rejected. Comparing the groups in the motor fitness tests, significant changes were observed in the 200m test, squat (both legs), Y-balance test (left and right), agility, and balance tests between the DNS training group and the Corrective and Control groups. Similarly, in the physical fitness tests, significant changes were observed in the Schober test (flexion and extension), sit-and-reach test (extension), and extensor muscle endurance between the DNS training group and the other two groups.

4. Discussion and Conclusion

This study highlights the effectiveness of Dynamic Neuromuscular Stability (DNS) training as a form of motor control exercise in improving functional movements and single-leg squats. However, there is limited consensus in the research literature regarding the extent of the effect of DNS training on more complex functional movements (Mahdieh et al., 2018, 2020). DNS training, as a fundamental movement approach, is primarily focused on core stability and neuromuscular control, while also enhancing physical factors (Elphinston & Hardman, 2006). Wright et al. (2015) argued that DNS exercises as fundamental movements improve only the trained movement components and have no impact on overall functional movements. In contrast, some researchers believe that DNS exercises, as fundamental movement skills, are essential and safe for learning complex motor skills (Oliver et al., 2011). This group of researchers considers DNS exercises as building blocks for general and specialized motor patterns in sports, and therefore, they argue that sports training programs should primarily focus on fundamental motor skills. Although it is necessary to practice functional movements to improve them, it is equally important to address deficiencies in fundamental movements, as they can hinder performance. Overall, these seemingly opposing perspectives suggest that proficiency in fundamental movements is a necessary but not sufficient condition for readiness in specialized functional movements. However, it has been shown that practicing fundamental movements can improve general functional movements to some extent (Mahdieh et al., 2020). Posture control and breathing mechanics are closely related from a neuromuscular and mechanical perspective (Hudson et al., 2011). Weakness in the core muscles, which also play a role in respiration, has an early negative effect on postural stability and balance (David et al., 2012). Among the deep connections between posture and breathing, the diaphragm plays a key role in both. Smith et al. (2015) explained that, in the absence of dysfunction or disease, the diaphragm and the transverse abdominis simultaneously provide posture and respiration control. They noted that weakness in breathing patterns and respiratory disorders can impair the postural function of these muscles, leading to compensatory breathing patterns, loss of spinal stability, and impaired motor control. Similar issues may arise due to pelvic floor muscle weakness, which can affect the mechanical stability of the spine and negatively impact its strength and flexibility (Russell & Kolnes, 2006; Smith, 2012).

Central stability during static and dynamic tasks and breathing patterns is achieved and coordinated through the synergistic contraction of the deep neck flexors, spinal extensors, diaphragm, abdominal muscles, and pelvic floor muscles, which regulate intra-abdominal pressure and provide anterior stability to the lumbopelvic system (Frank et al., 2013; Chaitow et al., 2014). Therefore, one of the goals of this study was to examine whether dynamic neuromuscular stability training impacts dynamic postural control, agility, and upper limb stability. The results of the data analysis showed that DNS training, as a motor control exercise, significantly improved dynamic postural control, agility, and upper limb stability after the intervention. These changes may be interpreted as more precise balance control or less effort required to maintain posture, reflecting a clear improvement in postural control.

Other researchers have reported similar findings (Miketa et al., 2018, 2020). Miketa et al. (2017) examined the impact of DNS training on postural stability and found that 61 sessions of respiratory training eliminated compensatory and uncoordinated contractions during activities requiring stability, improved intra-abdominal pressure, enhanced awareness of proper abdominal muscle engagement in maintaining intra-abdominal pressure, reduced predetermined compensatory patterns, and improved postural stability. Kolář et al. (2012) stated that a natural breathing pattern depends on a stable lower trunk. The diaphragm establishes the connection between respiration and trunk stability.

5. Limitations of the Study

1. **Lack of a true control group:** If the control group in this study had not undergone any other exercises, it would have been easier to determine the specific effects of DNS and corrective exercises. A control group receiving no interventions would allow for more accurate comparisons.
2. **Duration of intervention:** The time frame of the intervention (several weeks) may not have been sufficient to produce sustainable and significant changes. Longer-term studies could examine the long-lasting effects of these exercises.
3. **Uncontrolled variables:** In the real-world environment of firefighters, multiple factors (e.g., occupational stress, environmental conditions, task type) could influence respiratory, physical, and motor performance, making it challenging to control all variables during the study.

6. Conclusion

This study confirms the significant impact of Dynamic Neuromuscular Stability (DNS) training on functional movements and physical fitness in firefighters. DNS exercises, designed based on developmental neuro-motor reflex chains, can enhance functional movements and correct systemic disorders. These exercises are highly recommended for firefighters as part of their annual training programs to improve performance and prevent injuries.

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My name is Ala Taghavi Ramazani, born on June 29, 1999. I was born into a sports-oriented family in Iran, and with the encouragement of my parents, I began practicing sports at the age of four or five. I obtained my Bachelor's degree in Sport Sciences with a GPA of 17/86 out of 20, and subsequently completed my Master's degree in Sports Injuries and Corrective Movements with a GPA of 18/12 out of 20. Currently, I am pursuing my Master's degree at the University of Tor Vergata in Rome, Italy, majoring in Physical Activity and Health Promotion. The motivation behind conducting this research and selecting the topic of firefighting and physical activity arises from my deep interest in this field and the limited number of studies that have been carried out on the subject. I sincerely hope that this collaboration will mark the beginning of a productive and long-term partnership between us.

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