Human Movement Science 70 (2020) 102568

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Effects of dynamic neuromuscular stabilization (DNS) training on functional movements

Leili Mahdieh[a], Vahid Zolaktaf[a,*], Mohammad Taghi Karimi[b]

[a] Department of Sport Injuries and Corrective Exercises, Faculty of Exercise Sciences, University of Isfahan, Isfahan, Iran
[b] School of Rehabilitation Sciences, Shiraz University of Medical Sciences, Shiraz, Iran

ARTICLE INFO

Keywords:
Functional movements (FMs)
Dynamic neuromuscular stabilization (DNS)
Physical fitness (PF)
Injury

ABSTRACT

Functional movements (FMs) dysfunction is a potential risk factor of injuries. A variety of training strategies is proposed to improve the performance of FMs. We investigated if a system of fundamental movement exercises called Dynamic Neuromuscular Stabilization (DNS) could improve FMs. Thirty-four female students were randomly assigned into two matched groups to receive DNS (the study protocol) versus physical fitness (PF) training. The groups practiced for six-weeks (three sessions of 50 min weekly). We used five FMs tests as pre and post measures of exercise effectiveness. Repeated Measures ANOVA showed a significant interaction in all five FMs tests in favour of DNS group ($F_{(1,32)} \geq 4.13$, $P \leq .001$ and $\eta^2 \geq 0.29$), meaning that DNS group had a higher progress rate compared to that of PF group. Based on Eta-square coefficients, the highest and lowest differences in the progression rate were observed in Y-Balance and Functional Movement Screening Tests, respectively. Our findings supported the hypothesis that fundamental movements of DNS could be used to improve FMs. However, the progression coefficient declined as FMs became more specific. Lower progression of “specific FMs” suggests that it might prove more effective to add “specific training” to “fundamental training” for them.

1. Introduction

Studies have shown that nearly 80% of sports injuries are linked with the musculoskeletal system and mainly affect the lower extremity (Patel & Nelson, 2000). The increased injuries to the lower extremity are probably due to the fact that the lower extremity bears the weight both in static and dynamic positions. There is a higher risk of musculoskeletal injuries in women compared to men and the elderly compared to young people (De Loes, 1995; Louw, Manilall, & Grimmer, 2008). Nevertheless, both genders at all ages may become prone to the injuries. Over 70% of musculoskeletal injuries are caused intrinsically (Boden, Dean, Feagin, & Garrett, 2000), i.e. they are mainly caused by internal factors. Researchers studying musculoskeletal injuries believe that one of the major factors behind intrinsic injuries is “functional movement dysfunction”, a neuromuscular condition that results from “Dynamic Postural Instability” (Cook, Burton, Kiesel, Bryant, & Torine, 2010; Sahrmann, 2002). The prevention of musculoskeletal injuries is a critical challenge facing the studies on physical activities. If dynamic postural instability and consequently functional movement dysfunctions are discovered to be the major causes of some intrinsic injuries, better preventive results may be achieved by screening and diagnosing the people at risk and engaging them in functional corrective programs.

Recent literature on corrective exercise and sports injuries has paid special attention to functional movements (FMs). FMs refers to both basic FMs (BFMs) and sport-specific FMs (SFMs). BFMs includes movements such as step, squat and lunge, while SFMs includes

* Corresponding author.
E-mail address: v.zolaktaf@spr.ui.ac.ir (V. Zolaktaf).

https://doi.org/10.1016/j.humov.2019.102568
Received 19 April 2019; Received in revised form 22 December 2019; Accepted 23 December 2019
Available online 13 January 2020

movements such as spiking in volleyball and javelin throw in track and field. A wide variety of tests is introduced to evaluate BFMs and SFMs (Santana, 2016). A balance between mobility and stability in joints through the kinetic chain is a prerequisite for performing fundamental movement patterns, which, in turn, is a prerequisite for performing BFMs. BFMs themselves are prerequisites for SFMs. In other words, to perform SFMs, you need to add strength, flexibility, endurance, coordination, balance and movement efficiency to BFMs (Cook et al., 2010). In our extensive search, five BFMs tests having good psychometric properties (validity, reliability, objectivity) were more noticeable (Ageberg et al., 2010; Kraus, Schutz, Taylor, & Doyscher, 2014; Padua et al., 2009; Padua et al., 2011; Shaffer et al., 2013). The tests were: 1. Y balance (YB); 2. Landing Error Scoring System (LESS); 3. Landing Error Scoring System-Real Time (LESS-RT); 4. Single-leg Squat (SLS); 5. Functional Movement Screening (FMS). These tests involve the participants with functional positions, where imbalance between mobility and stability in joints manifest themselves in the performance, eventually leading to compensatory movement patterns in the kinetic chain. The first four tests are introduced sooner and involve relatively more complex movements, while the fifth test, i.e. FMS, is a rather recently-developed test involving relatively simpler movements (Warren, Lininger, Chimera, & Smith, 2018).

The relationship between functional movement tests and the risk of injuries has been previously investigated (Bardenett et al., 2015; David Robert Bell, Smith, Pennuto, Stiffler, & Olson, 2014; Chapman, Laymon, & Arnold, 2014; Chimera, Smith, & Warren, 2015; Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Hammes, Aus der Funten, Bizzini, & Meyer, 2016; Kyle Kiesel, Plisky, & Voight, 2007; Kraus et al., 2014; Letafatkar, Hadadnezhad, Shojaedin, & Mohamadi, 2014; O Connor, Deuster, Davis, Pappas, & Knapik, 2011; Padua et al., 2015; Ugalde, Brockman, Bailowitz, & Pollard, 2015; Warren, Smith, & Chimera, 2015; Wieczorkowski, 2010). A systematic review by Kraus et al. has shown that FMS overall score could be used to anticipate the risk of injury in team sports (Kraus et al., 2014). Also, a systematic review by Bonaza et al. showed that an overall score of 14 or less in the FMS test increases the risk of injury, which is the confirmation of the predictive validity of this test (Bonazza, Smuin, Onks, Silvis, & Dhawan, 2017). By carrying out a research on 200 athletes, Chimera et al. (2015) concluded YBT and FMS scores were influenced by injury history and sex (Chimera et al., 2015). Padua et al. (2015) performed an investigation on 829 teenager football players during an on-season in order to assess LESS test ability in identifying people who were at risk of ACL injury. They concluded that non-injured persons obtained lower LESS scores than injured persons. LESS test can, in fact, be used as a screening tool to detect people at risk of ACL injury (Padua et al., 2015). It was revealed that people with reconstructed ACL had lower LESS scores, indicating their worse landing mechanism compared to the non-injured group. Researchers concluded LESS could prove useful for the evaluation of landing error in athletes, and for the rehabilitation before returning to the sports activity (David Robert Bell et al., 2014). In a cross-sectional study to investigate SLS and Drop-Jump, people with lower SLS scores also demonstrated higher values of dynamic knee valgus. The researchers suggested that SLS test could serve as a logical tool to evaluate dynamic knee valgus and risk of lower extremity injury (Ugalde et al., 2015).

DNS correction exercises are designed based on developmental kinesiology, which studies the progressive stages of motor behaviour in infants from their birthdate to the time when they begin to walk. In DNS viewpoint, lack of motor development during infancy leads to neuromuscular disorders, which, in their turn, will emerge as biomechanical deficits in later ages. Biomechanical deficits may also eventually cause anatomic deficits. The consequence of this assumption is that the process of movement correction should start with the correction of neuromuscular disorders. An example is the belief which holds that the first step in corrective exercise is to perform a respiratory assessment, and to correct breathing patterns if needed (Frank, Kobesova, & Kolar, 2013). They maintain that respiratory muscles play a crucial role in static and dynamic postural stability. After the correction of breathing patterns, this approach then engages in correcting the fundamental movements as they emerge during the first year of life. The infants experience fundamental movements in various positions throughout their developmental process. The infant's nervous and muscular systems require a close coordination through the process in order to defy gravity, maintain the posture and improve the mobility. Based on the DNS standpoint, motor patterns are recalled by the central nervous system (CNS) according to genetic staging. In other words, certain fundamental movement patterns are already set up in a healthy infant and are stored in the CNS throughout adulthood (Frank et al., 2013).

DNS is a neuromuscular approach which uses infants' movement developmental process to diagnose and treat motor disorders (Frank et al., 2013; Kolar & Kobesova, 2010). In the neuromuscular view, the root of motor deficiency is two things: lack of exercise at the right time, and having an obstacle when practicing the movement. For example, if running is practiced at its proper time (infancy) and barefoot on a dirt surface, it will automatically create the best running pattern. In contrast, if the practices take place later than the right time, it might create wrong patterns of movements. In early ages of life, a child mostly relies on her own internal resources, such as kinesthetic sense and unconscious genetic patterns, but as they gradually get older, they rely on external resources, such as visual stimulations and educational resources. Adapting to environmental obstacles, such as the use of synthetic shoes, also contributes to the cause. In this way, many people are not able to run several hundred meters despite the fact that they have been created to run tens of kilometers per day (Lantinga, 2013).

Muscular pains and functional deficits originate from three types of factors: psychosocial, pathophysiologic, and pathokinesiologic. DNS approach merely addresses the muscular pains and functional deficits which have a pathokinesiologic source with no sign of anatomical deformities. This kind of pathokinesiologic deficits have neuromuscular causes that, in its turn, can result in biomechanical misuse. Repetition of misuse is one the main origins of anatomical deficits. Neuromuscular disorder includes control dysfunction and disturbed coordination. Biomechanical misuse includes incorrect core position and incorrect technique, collectively called misuse. Anatomical deficits include malalignment, imbalance, and asymmetry (Harris & Dyrek, 1989; Rose, 1986). In summary, the DNS authors believe that neuromuscular disorders are the main origin of most biomechanical misuses and even some anatomical deficits. These complications, therefore, could be prevented or even treated by neuromuscular restoration.

Although practicing DNS-based fundamental movements seems logical, its effectiveness on "fundamental movements" has yet to be investigated in depth. In a comprehensive search for the studies on the application of DNS exercises, a number of reports were found concerning the use of these exercises to treat diseases such as migraine, Posterior Cortical Atrophy (PCA), and chronic musculoskeletal pains (Bokarius, 2008; Juehring & Barber, 2011; Oppelt, Juehring, Sorgenfrey, Harvey, & Larkin-Thier, 2014; Yoon & You, 2017). Moreover, the effect of DNS on strengthening the muscles of the hand has also been demonstrated (Kobesova, Dzvonik, Kolar, Sardina, & Andel, 2015), but no study was found about the effect of DNS on the correction of FMs. As the DNS exercises merely involve practicing fundamental movements, the question is whether they can also help to improve basic and specific functional movements. To provide an answer, the current study examined five functional tests before and after a DNS program in order to identify the degree to which DNS exercises affect them.

2. Methods

The research was approved by the Research Ethics Board of the University of Isfahan (Ethics code: IR.UI. REC.1397.069). The sample included 34 healthy non-athlete female students who met the following requirements: no participation in any other exercise activities during the research period, no medically necessary restrictions to perform exercises; and, no suffering from any untreated injury during the last 6 months before the study. The sample was randomly assigned into two matched groups based on height and weight criteria. According to the sample size estimation equation proposed by Sullivan, based on an alpha of 0.05, a power of 0.75, and an effect size of 0.69, the sample size was considered to be 14 in each group (Sullivan, 2016). Our estimation on effect size was based on our previous study (Jafari, Zolaktaf, & Ghasemi, 2020). According to our previous experiences, attrition rate was estimated to be < 10% for PF group. We assumed, at most it will be 30% for DNS group. Hence the sample size was taken as 19 and 15 for DNS and PF groups, respectively. Nevertheless, no attrition occurred. All participants initially filled out an informed consent form.

Study procedure included: preparing the setup, registering participants, administrating the pre-tests, carrying out the exercise program, and administrating the post-tests. The study criteria tests were consisted of five functional movement tests (FMTs), including FMS (Cook et al., 2010), single-leg squat (Ugalde et al., 2015), Y Balance (Plisky et al., 2009), landing error scoring system (Clark & Lucett, 2010) and landing error scoring system real-time (Padua et al., 2011). Each test was conducted and scored based on its own instruction (Clark & Lucett, 2010; Cook et al., 2010; Padua et al., 2011; Plisky et al., 2009; Ugalde et al., 2015). SLS and YB tests were administered on the right leg. SLR was carried out as defined by Ugalde et al. (2015). They introduced three errors for the test: arms flailing, the Trendelenburg sign, or collapse of the supporting knee into valgus. In a pilot study, we found out that the participants were likely to commit five additional errors, namely touching the ground, flexing the hip, flexing the trunk, flexing the knee, and rotating the trunk. As a result, we considered eight errors to affect the scoring process. A higher score means a higher number of errors. Ten kinesiologists verified the face and the logical validity of this method. Test-retest reliability of the method was 0.91 for a 6-week gap period.

The control group performed a physical fitness (PF) routine exercise (Appendix A), whereas the experimental group followed a DNS exercise protocol (Appendix B) for a whole period of 6 weeks (three 50-min sessions per week). PF group's protocol was based on the overload principle and involved 5 min warm-up, 10 min aerobic, 10 min sprinting, 10 min agility, 10 min strength, and 5 min cool-down exercises. DNS group's protocol involved 5 min warm-up, 40 min DNS movements accompanied with breathing exercises, and 5 min cool-down. According to the DNS approach (Frank et al., 2013; Phillips, 2012), the exercises included diaphragmatic breathing, Baby Rock (supine 90–90), Prone, Rolling, Side Lying, Oblique Sit, Tripod, Kneeling, Squat and Czech Get Up (CGU). Week one specifically involved training and practicing basic DNS exercises (movements are shown in Appendices C and D). The complexity of the exercises increased gradually by adding a new task to an already practiced task every week (in comparison with the preceding week). An increase in the complexity of a task helped the performer to automate her performance. We used the dual-task paradigm to examine if the task is automated or not (e.g. no new task should disturb the diaphragmatic breathing) (Wickens, 1991). In other words, in DNS training, the overload principle is exerted by making the exercises more complex, while in fitness training, it is exerted by increasing weights, repetitions, time, distance, etc. The data was statistically analysed in SPSS V. 23 using Repeated Measures Analysis of Variance (RM-ANOVA) at $P \leq .05$.

3. Results

In this study, attendance rate was calculated based on the participants' attendance at exercise sessions divided by the total number of sessions (18 sessions). Mean attendance rate was 94% for DNS group and 92% for PF group. Table 1 shows the demographic data of participants, and Table 2 presents the data on RM-ANOVA. As shown in Table 2, the interaction effect of time and group for all five

Table 1
Demographic data of participants.

Factor		N	Age (year) (Mean ± SD)	Height (cm) (Mean ± SD)	Weight (kg) (Mean ± SD)	BMI (kg/m^2) (Mean ± SD)
Group	DNS	19	18.8 ± 0.68	160.4 ± 5.53	61.4 ± 14.41	23.7 ± 4.67
	PF	15	18.9 ± 0.91	160.5 ± 3.16	61.2 ± 12.10	23.8 ± 4.71
P (sig)			0.089 (0.929)	0.030 (0.976)	0.045 (0.964)	0.036 (0.972)

DNS = Dynamic Neuromuscular Stabilization, PF = Physical Fitness, P = *P*-value, sig = significant, SD = Standard Deviation, cm = centimeter, kg = kilogram, m = meter.

Table 2
Information on RM-ANOVA test in the descending order of Eta-squared.

Variable	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Progress percentage	Interaction $df_{(1,32)}$	Eta-squared η^2
FMS (0 – 21)	DNS	10.8 ± 1.34	17.4 ± 1.60	60	F = 250.42	0.89
	PF	11.2 ± 2.36	11.7 ± 2.52	5	*P* < .001	
SLS (R) (0–8)	DNS	4.1 ± 1.25	0.8 ± 0.76	80	F = 67.66	0.68
	PF	3.7 ± 1.22	3.3 ± 1.04	11	P < .001	
LESS-RT (0–15)	DNS	9.9 ± 2.17	7.4 ± 2.40	26	F = 30.15	0.48
	PF	9.4 ± 2.19	9.0 ± 2.13	4	P < .001	
LESS (0–15)	DNS	9.6 ± 2.69	7.2 ± 2.71	25	F = 22.58	0.41
	PF	9.0 ± 2.59	8.6 ± 2.44	4	P < .001	
YB (cm)	DNS	84.9 ± 6.83	94.6 ± 5.75	12	F = 13.37	0.29
	PF	86.4 ± 9.17	89.3 ± 7.96	3	*P* = .001	

FMS = Functional Movement Screening, SLS = Single Leg Squat, YB = Y Balance, LESS = Landing Error Scoring System, LESS-RT = Landing Error Scoring System-Real Time.
SD = standard Deviation, df = degrees of freedom, cm = centimeter.
Eta-squared: calculated by SPSS for repeated measure ANOVA.

functional movement tests were significant (P ≤ .05). The interaction effect compares the changes within DNS and PF groups from pre-test to post-test. Fig. 1 demonstrates the linear curve obtained for the FMS test. As shown, progress rate in FMS scores was 12 times better in DNS group (60%) vs. PF group (5%). Eta-square presents the effect size of this statistical analysis, i.e. 0.89. Fig. 2 demonstrates the linear curves obtained for other functional tests. According to Figs. 1 and 2, although both PF and DNS groups have made significant progression, the rate of progression was higher in DNS group compared to PF group in all five FMTs. The overall shape is almost the same for all five functional movement tests, with the only difference being observed in the effect size of changes. A bigger effect size indicates a stronger effect of the training programs (DNS versus PF) on the functional test.

4. Discussion

Statistical analysis revealed a significant interaction in favour of DNS group (versus PF group) in all five functional tests, i.e. the progress made by DNS group was significantly higher than that of PF group ($p \leq .05$). Eta squared is a measure of the effect size in terms of its significance and size (Field, 2005). A higher Eta squared indicates that DNS group enjoys a higher progress rate compared to PF group. As for r^2 or R^2, η^2 ranges between 0 and 1. Eta squared could be interpreted as small, medium, and large when they respectively equal 0.02, 0.13, and 0.26 (Pierce, Block, & Aguinis, 2004). In this study, η^2 values were 0.29, 0.41, 0.48, 0.68 and 0.89 for YB, LESS, LESS-RT, SLS, and FMS tests, respectively. These large effect sizes verify that DNS exercises significantly affected all five FMs. However, the effect size varied for each functional movement. Given the complexity and difficulty of the FMs in the study, it was noticed that an increase in the movement complexity would decrease the effect size. The findings point out to the conclusion that DNS-based exercises involving fundamental functional movement are necessary for the improvement of FMs, but may also need a complement in the form of specific exercises. The need becomes more evident as FMs take a more complicated form.

Our study showed that practicing fundamental movements positively influenced all five FMTs, indicating that fundamental movement drills are likely to improve FMs. Apparently, there is no consensus about the effect size of the fundamental functional exercises on more complex forms of FMs (David R. Bell, Oates, Clark, & Padua, 2013; Frost, Beach, Callaghan, & McGill, 2012; K. Kiesel, Plisky, & Butler, 2011; Kyle Kiesel et al., 2007; Wright, Portas, Evans, & Weston, 2015). Although FMs exercises typically focus on core stability and neuromuscular control, they simultaneously improve muscle flexibility and strength (Elphinston & Hardman, 2006). Wright reported that fundamental movement exercises only improve the specific movements practiced, and do not influence the overall FMs (Wright et al., 2015). At the other end of the spectrum are researchers who believe that practicing fundamental movements is essential for the safe learning of complex skills. Oliver et al. believe that "training programs that target fundamental movement quality in young people are an essential component of athletic development to allow safe progression to more complex training" (Oliver, Lloyd, & Meyers, 2011). In this viewpoint, fundamental movement skills are seen as building blocks for specific

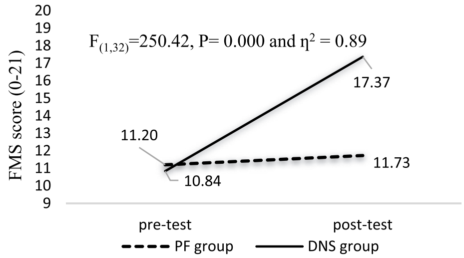


Fig. 1. Changes from pre-test to post-test in FMS scores.

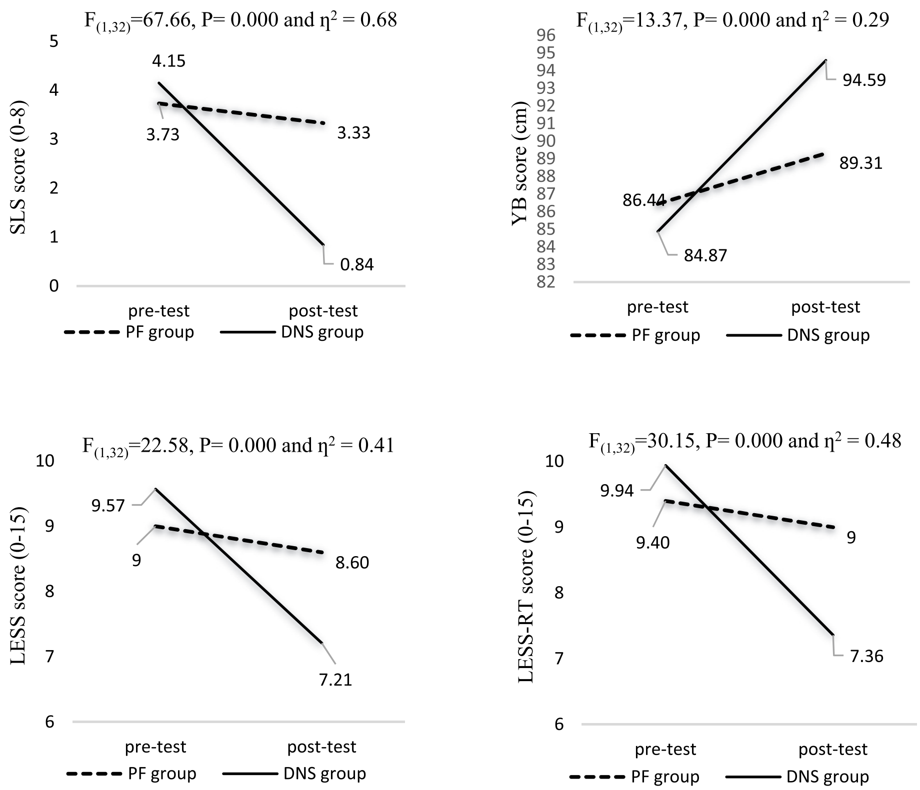


Fig. 2. Changes from pre-test to post-test in Single Leg Squat (SLS), Y Balance (YB), Landing Error Scoring System (LESS), Landing Error Scoring System-Real Time (LESS-RT) scores.

movement patterns, so the focus of the practices should primarily be placed on fundamental movement skills (Deli, Bakle, & Zachopoulou, 2006). Strictly speaking, although improving FMs require practicing the movements themselves, it should also be noted that unskilful performance of fundamental movements may raise problems. The consequence of these seemingly conflicting views is that skillfulness in fundamental movements is the necessary (but not the necessary and sufficient) condition to achieve skillfulness in any SFMs, although it has been shown that practicing FMs may result in a relative improvement of BFMs. As an example, Kiesel carried out a study on American professional soccer players whose FMs score rose after the intervention of an off-season exercise program (K. Kiesel et al., 2011).

Some researchers believe that human motor development happens gradually and should follow its phases one by one to prevent the person from developing motor deficits, pain and injuries (Cook et al., 2010; Frank et al., 2013). According to Cook's et al. (Cook et al., 2010), motor development begins by head and neck control, and then proceeds to rolling, creeping, kneeling, squat, standing, stepping, walking, climbing, and running. Frank et al. (Frank et al., 2013) presented the motor development phases up to the 13th month in details. The infants' natural life must include enough opportunities to practice these phases of fundamental motor development. The absence of any of these initial motor development phases is likely to result in limited and impaired mobility. In industrial lifestyle, many children use baby walkers and grow up in closed spaces while wearing diapers, heavy clothing, and shoes. This deprives the children of good sensory and motor development opportunities, which can be created by baby games in diverse natural circumstances. The fundamental functional movements (FFMs) patterns acquired during childhood need to be maintained by suitable practice opportunities during adulthood. Otherwise, the person may develop movement disorders (Cook et al., 2010). Unfortunately, neither the society, nor home, school or elsewhere offer children enough opportunities to practice and master FMs. This unsatisfied need accompanies the children until youth and adulthood, and even escalates in some cases.

DNS viewpoint holds that fundamental movement patterns are inherently preplanned in healthy children, and appear spontaneously at their right time if no barriers to practice erects (Frank et al., 2013). Lack of access to a natural environment suitable for babies, children, the youth, and adolescents to perform physical activities either prevents the basic formation of FFMs in motor neural pathways, or causes it to fade out at older ages, if formed at all. As a result, the DNS approach recommends to recall essential sensory and motor mechanisms from the CNS by practicing FFMs, eventually resulting in a corrected movement pattern (Frank et al., 2013). Our study showed that practicing DNS-based fundamental movement patterns also brought about a performance improvement in functional movement tests. As evident in Table 2 and discussed in the first paragraph of this section, the effect size of the fundamental exercises was inversely proportional to the complexity of functional movement tests, i.e. the effect size reduced as the FMs under the study became more complex. FMS is similar to DNS in principle, as it is also rooted in developmental kinesiology and movement program of a healthy baby. In fact each FMS movements is connected with a movement of the baby's motor developmental period

(Phillips, 2012). Therefore, it sounds logical that the highest effect sizes of our study went to FMS in comparison with more complicated functional tests. Generally speaking, it can be postulated that practicing fundamental movements allow for an improvement in simple FMs, but the effect reduces as the FMs appear in more specific and complicated forms, hence making it necessary to train specific practices for more specific skills. In total, DNS-based fundamental movement exercises seem to be a necessary, though not a sufficient, condition to safely perform more complicated FMs.

5. Conclusions

The study demonstrated the effects of DNS-based FFMs on improving various FMs (η^2 from 0.29 to 0.89). Building skill in FFMs may also turn out to be useful for performing more specific FMs, such as sport skills, more effectively. More studies, nevertheless, need to be carried out to make firm and strong comments about it. For the time being, the study can reach to the conclusion that athletes' off-season annual training program could preferably incorporate an FFMs course to run for a few weeks. It would probably prevent intrinsic injuries caused by movement dysfunctions linked to neuromuscular disorders. The reason behind it is that many anatomical and biomechanical deficits originate from neuromuscular disorders. It is important to note that developing skills in FFMs is merely the starting point to avoid sports injuries, and a comprehensive preventive plan needs to cover some other aspects, such as: establishing health and sports oriented physical fitness, establishing specific neuromuscular control by specific functional training, avoiding overuse by allocating enough recovery time, and removing extrinsic causes of injury (e.g. inappropriate field and equipment, or aggression/violence).

Author statement

Leili Mahdieh: conceptualization, design of the research, methodology, and data analysis, and writing up.

Vahid Zolaktaf: supervision of all the steps of the study, conceptualization, design of the research, methodology, and data analysis, exercise protocol, and writing up.

Mohammad Taghi Karimi: writing up, reviewing and editing, and methodology.

Declaration of Competing Interest

The authors report no conflict of interest.

Acknowledgement

Many thanks to main sponsor of the study, respected authorities of the Faculty of Exercise Sciences, University of Isfahan. The current study was conducted with the contribution of students studying at Isfahan University of Technology (IUT). The author is truly grateful for the participants' cooperation. Also, special appreciation goes to the honoured head of Physical Education Office, Mrs. Mahnaz Manshouri, for facilitating the conditions required to conduct the study.

Appendix A. Training protocol of the PF group

Warm-up[a] (5 min)	Aerobic[b] (10 min)	Sprinting[c] (10 min)	Agility[a] (10 min)	Strength[d] (10 min)	Cool-down[e] (5 min)
Walking forward/backward/sideways while the hands move on different planes of motion simultaneously	Jogging	8 × 20 m 4 × 50 m 2 × 100 m	4 × 9 m shuttle test path *t*-test path Illinois test path Hexagon test path	Sit-ups Push-ups Plank Side-plank	Static stretch (hamstring/ quadriceps/ dorsi/ plantar/ adductor/ arm/ chest)

min: minutes, m: meters

[a] Every two weeks, the exercise pressure was increased by gradually increasing the repetition.

[b] The distance was 1200, 1400, and 1600 m respectively in first, second, and third two weeks.

[c] Every two weeks, running speed was increased.

[d] Every two weeks, the training pressure was increased by increasing repetition for sit-ups and push-ups and increasing static holding time for Plank and Side-plank.

[e] Every two weeks, the exercise pressure was increased by increasing static stretching time.

Appendix B. Training protocol of the DNS group

An overview of the training protocol of the DNS group is presented in Table B.1. Each training session consisted of five minutes of warm-up and five minutes of cool down. The remaining 40 min was divided into four ten-minute sections during which the main exercises were practiced. Table B.1 represents the movements included in main parts of every training session. To understand the meaning of abbreviations in Table B.1, details of every exercise is explained in Table B.2 to Table B.10.

Table B.1
Training protocol (DNS group) in six weeks.

Session	4 parts of main exercise, each part lasts for 10 min, and a total of 40 min			
	6–15 min	16–25 min	26–35	36–45
1	A_1-B_1-B_2	C_1-C_2-G_1	E_1-E_2-F_1-F_2	H_1-H_2-K_1-K_2
2	A_1-B_2-B_3	C_1-C_2-C_3-G_1	E_1-E_3-F_3	H_1-H_2-K_1-K_2
3	A_1-B_3-B_4	C_2-C_3-G_1-G_2	E_2-E_3-F_2-F_3	H_2-H_3-K_2-K_3
4	A_1-B_4-B_5	C_1-C_4-G_1-G_2-G_3	E_4-F_4	H_2-H_3-H_4-K_3-K_4
5	A_1-B_6-D_1	C_5-G_4	E_2-E_4-E_5-F_2-F_4-F_5	H_1-H_5-K_4-K_5
6	A_1-B_6-B_7-D_1-D_2	C_5-C_6-G_5	E_4-E_6-F_4-F_6	H_5-H_6-K_5-K_6
7	A_1-B_7-B_8-D_1-D_2	C_6-C_7-G_5-G_6	E_4-E_5-E_6-F_4-F_5-F_6	H_5-H_6-K_5-K_6
8	A_1-B_9-D_1-D_3	C_8-G_5-G_6-G_7	E_6-E_7-F_6-F_7	H_5-H_6-K_6
9	A_1-B_{10}-D_3-D_4	C_4-C_8-G_7-G_8	E_7-E_8-F_7-F_8	H_7-K_6-K_7
10	A_1-B_{10}-B_{11}-D_5-D_6-D_7	C_6-C_7-G_8-G_9	E_6-E_7-E_8-F_6-F_7-F_8	H_7-H_8-K_7
11	A_1-B_{11}-B_{12}-D_8-D_9	C_6-C_7-G_9-G_{10}	E_8-E_9-F_8-F_9	H_7-H_8-K_7-K_8
12	A_1-B_{12}-B_{13}-D_{10}-D_{11}	C_7-G_8-G_9-G_{10}	E_7-E_8-E_9-F_7-F_8-F_9	H_7-H_8-H_9-K_8
13	A_1-B_{14}-D_{10}-D_{11}-D_{12}	C_8-G_9-G_{10}-G_{11}	E_7-E_{10}-F_{10}-H_1	H_9-K_8-K_9
14	A_1-B_{15}-D_{13}-D_{14}	C_7-C_8-G_{10}-G_{11}	E_7-E_{11}-F_{11}-H_1	H_9-H_{10}-K_9
15	A_1-B_{16}-B_{17}-D_{15}-D_{16}	C_6-C_7-G_{11}-G_{12}	E_{11}-F_{11}-H_3	E_{10}-F_{10}-H_{10}
16	A_1-B_{18}-B_{19}-D_{17}-D_{18}	C_6-C_7-G_{13}	E_{11}-F_{11}-H_7	E_{10}-F_{10}-H_{10}
17	B_{20}-D_{19}	C_9-G_{11}-G_{12}-G_{13}	E_{11}-F_{11}-H_8	CGU
18	B_{21}-D20	C_9-G_{11}-G_{12}-G_{13}	E_{11}-F_{11}-H_9	CGU

Details of every exercise (e.g. A_1-B_1-B_2) is explained in Table B.2 to Table B.10. CGU stands for Czech Get Up exercise (Shown in Appendix D).

Table B.2
Different levels of breathing exercise (A_1-A_6).

Level	Breathing exercise
A_1	Learning and practicing diaphragmatic breathing at rest (lying, sitting, standing)
A_2	Practice to Maintain diaphragmatic breathing during maintaining Basic DNS Positions Statically
A_3	A_2 + Various movements of single arm or single leg
A_4	A_2 + mixed movements of one arm and one leg (on the same or opposite side of body) In a single plane of motion
A_5	A_2 + mixed movements of one arm and one leg (on the same or opposite side of body) In two different planes of motion
A_6	practicing diaphragmatic breathing during performing basic DNS movements

Table B.3
Different levels of Baby Rock (B_1-B_{21}).

Level	Baby Rock (Supine 90–90)
B_1	Maintaining static movement and focusing on diaphragmatic breathing
B_2	Single arm flexion/extension
B_3	Two hand flexion/extension simultaneously on elbow and shoulder joints or a combination of them
B_4	Moving both hands at the elbow and shoulder joints in different planes of motion with and without dumbbell
B_5	Flexion/extension of one arm and one leg (on the same or opposite side of body) simultaneously
B_6	B_4 without dumbbell
B_7	B_4 with dumbbell
B_8	B_5
B_9	Moving one arm and one leg (on the same or opposite side of body) simultaneously in two different planes of motion
B_{10}	Pressing the Pilates ball between both thighs and hip flexion/extention

(continued on next page)

Table B.3 (*continued*)

Level	Baby Rock (Supine 90–90)
B_{11}	Pressing the Pilates ball between both thighs + Single / Paired arm Movement in different planes of motion
B_{12}	B_{11} + Knee flexion/extension
B_{13}	B_{12}+ dumbbell/theraband
B_{14}	B_{11} + Knee/hip flexion/extension
B_{15}	B_{11} (Using theraband loop instead of Pilates ball)
B_{16}	B_{11} + hip extension
B_{17}	B_{15} + dumbbell
B_{18}	B_{15} + theraband loop Around the legs + dumbbell
B_{19}	B_{18} + hip extension
B_{20}	Combining Baby Rock and Rolling
B_{21}	B_{20} + dumbbell

NOTE 1. Keeping the torso steady in these movements is a kind of unconscious training of the core muscles.
NOTE 2. From B2 exercise onwards, breathing is unconsciously performed diaphragmatically.
NOTE 3. In complex movements, note that the knees do not have a varus / valgus position.
NOTE 4. B_1 to B_5 is performed while "leaning the feet against the wall", and B_6 to B_{21} without leaning.

Table B.4
Different levels of Prone (C_1-C_9).

Level	Prone
C_1	Maintaining static movement and focusing on diaphragmatic breathing
C_2	Pressing two forearms to the ground
C_3	C_2 + Transferring weight to the flexed leg
C_4	C_3 + Lifting the upper trunk
C_5	C_1 + Shoulders horizontal flexion
C_6	C_5 + hip hyperextension for extended knee
C_7	C_5 + dumbbell
C_8	C_6 + The straight foot is bent and the dumbbell is kept behind the bent knee
C_9	Pressing two hands on the ground while simultaneously lifting the trunk and thighs from the ground to keep weight on the knees and palms

NOTE 1. Basic Position: neck and trunk hyperextension movement, keeping weight on the forearms, and hip and knee flexion in one leg.
NOTE 2. Note that when lifting the body from the ground, we should not have flexion or hyperextension in our back.

Table B.5
Different levels of rolling (D_1-D_{20}).

Level	Rolling
D_1	Short rolling to the right and left
D_2	Being fixed in rolling sideways with short range (three diaphragmatic breathing)
D_3	D_2 (for the length of time required for five diaphragmatic breaths)
D_4	D_2 + shoulder flexion/extension
D_5	D_2 + Movement of one arm and one leg (on the same or opposite side of body) simultaneously in different planes of motion
D_6	D_4 + dumbbell
D_7	D_5 + dumbbell (hand/behind the knee)
D_8	D_1 + dumbbell (hand/behind the knee)
D_9	D_1 + Static pressure on Pilates ball between both hands for 10 seconds + stretching theraband loop around the thighs
D_{10}	D_1 + Dynamic pressure on Pilates ball between both hands for 10 times + stretching theraband loop around the thighs
D_{11}	D_1 + Dynamic pressure on Pilates ball between both hands for 10 times + the same for the thighs
D_{12}	D_1 (long range)
D_{13}	D_3 (long range)
D_{14}	D_{13}+ Movement of one arm and one leg (on the same or opposite side of body
D_{15}	D_{12} + dumbbell (hand/behind the knee)
D_{16}	D_{12} + Pressing the Pilates ball between both hands + stretching theraband loop Around the thighs/legs
D_{17}	D_{13} + Light hits the Pilates ball between both hands + stretching theraband loop Around the thighs
D_{18}	D_{13} + Light hits the Pilates ball between both hands + hip extension
D_{19}	Combining Rolling and Side Lying
D_{20}	D_{19} + dumbbell

NOTE 1. Keeping the torso steady in these movements is a kind of unconscious training of the core muscles.
NOTE 2. In complex movements, note that the knees do not have a varus / valgus position

Table B.6
Different levels of side lying (E_1-E_{11}).

Level	Side lying
E_1	Maintaining static movement and focusing on diaphragmatic breathing
E_2	Arm movement in different planes of motion
E_3	leg movement in different planes of motion
E_4	Moving arm/leg in different planes of motion
E_5	E_2 + dumbbell
E_6	E_4 + theraband
E_7	Lifting the torso from the ground by pushing the lower hand on the ground
E_8	E_7 + dumbbell
E_9	E_8 + movement of arm/leg in different planes of motion
E_{10}	Combining side lying and oblique sit
E_{11}	E_{10} + dumbbell

NOTE 1. Keeping the torso steady in these movements is a kind of unconscious training of the core muscles.

Table B.7
Different Levels of Oblique Sit (F_1-F_{11}).

Level	Oblique sit
F_1	Maintaining static movement and focusing on diaphragmatic breathing
F_2	Arm movement in different planes of motion
F_3	Leg movement in different planes of motion + knee/hip flexion/extension
F_4	Moving arm/leg in different planes of motion simultaneously
F_5	F_2 + dumbbell/theraband
F_6	F_4 + dumbbell/theraband
F_7	F_1+ lifting the hip and holding it about two inches above the ground
F_8	F_7 + Moving arm/leg in different planes of motion simultaneously
F_9	F_8 + dumbbell/theraband
F_{10}	Combining Oblique Sit and kneeling
F_{11}	F_{10} + dumbbell

NOTE 1. Keeping the torso steady in these movements is a kind of unconscious training of the core muscles.

Table B.8
Different Levels of Tripod (G_1-G_{13}).

Level	Tripod
G_1	Maintaining static movement as stool and focusing on diaphragmatic breathing
G_2	Arm movement in different planes of motion (flexed knees)
G_3	leg movement (hip/knee joint) in different planes of motion (flexed knees)
G_4	opposite leg/arm movement in different planes of motion (flexed knees)
G_5	G_2 (extended knee)
G_6	G_3 (extended knee)
G_7	G_4 (extended knee)
G_8	Being fixed in Tripod position (two diaphragmatic breathing)
G_9	G_5 + stretching theraband loop Around the thighs
G_{10}	G_9 + dumbbell (hand)
G_{11}	G_6 + stretching theraband loop Around the thighs
G_{12}	G_7 + stretching theraband loop Around the thighs/legs
G_{13}	Being fixed in Tripod position (five diaphragmatic breathing)

NOTE 1. Keeping the torso steady in these movements is a kind of unconscious training of the core muscles.

Table B.9
Different levels of kneeling ($H_1 - H_{11}$).

Level	Kneeling
H_1	Maintaining static movement and focusing on diaphragmatic breathing
H_2	Arm movement in different planes of motion
H_3	H_2 + dumbbell
H_4	H_2 + theraband
H_5	Knee extension (short range)
H_6	H_5 + Arm movement in sagittal plane
H_7	H_5 + Arm movement in different planes of motion
H_8	H_7 + dumbbell
H_9	Knee extension (full range) + Arm movement in sagittal plane
H_{10}	Combining kneeling and squat
H_{11}	H_{10} + dumbbell

NOTE 1. Keeping the torso steady in these movements is a kind of unconscious training of the core muscles.

Table B.10
Different Levels of Squat (K_1-K_9).

Level	Squat
K_1	Performing short-range squat and focusing on diaphragmatic breathing (parallel hands on horizontal plane)
K_2	Maintaining static movement and focusing on diaphragmatic breathing (parallel hands on horizontal plane)
K_3	K_1 (parallel hands next to the ear on frontal plane)
K_4	K_3 (long rang) + dumbbell
K_5	K_2 (long rang) + Arm movement in different planes of motion
K_6	K_5+ dumbbell/theraband
K_7	K_5+ ankle plantar flexion
K_8	K_1 (long rang) + Arm movement in different planes of motion (dumbbell/theraband)
K_9	K_8+ stretching theraband loop Around the thighs

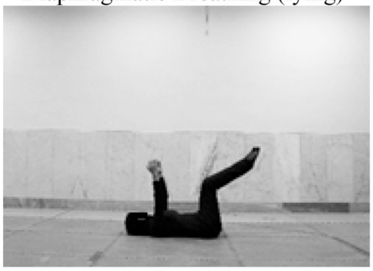
NOTE 1. Keeping the torso steady in these movements is a kind of unconscious training of the core muscles.

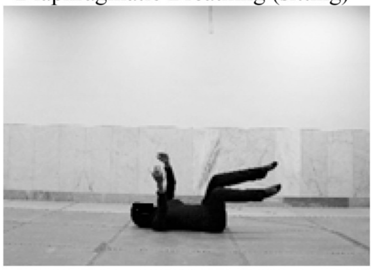
Appendix C. Starting positions of DNS training protocol


Diaphragmatic Breathing (lying)

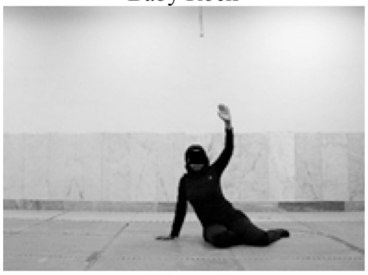

Diaphragmatic Breathing (sitting)

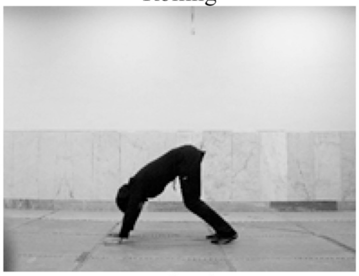

Diaphragmatic Breathing(standing)

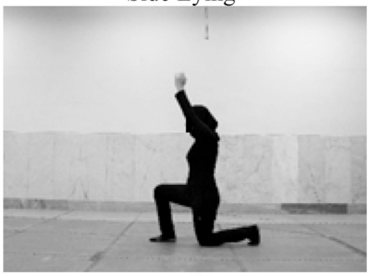

Baby Rock

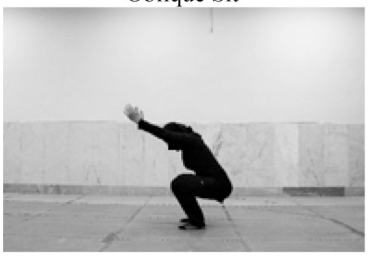

Rolling

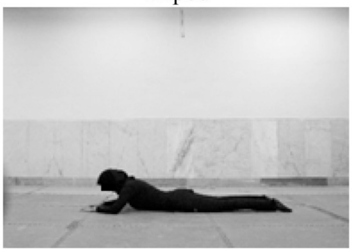

Side Lying


Oblique Sit

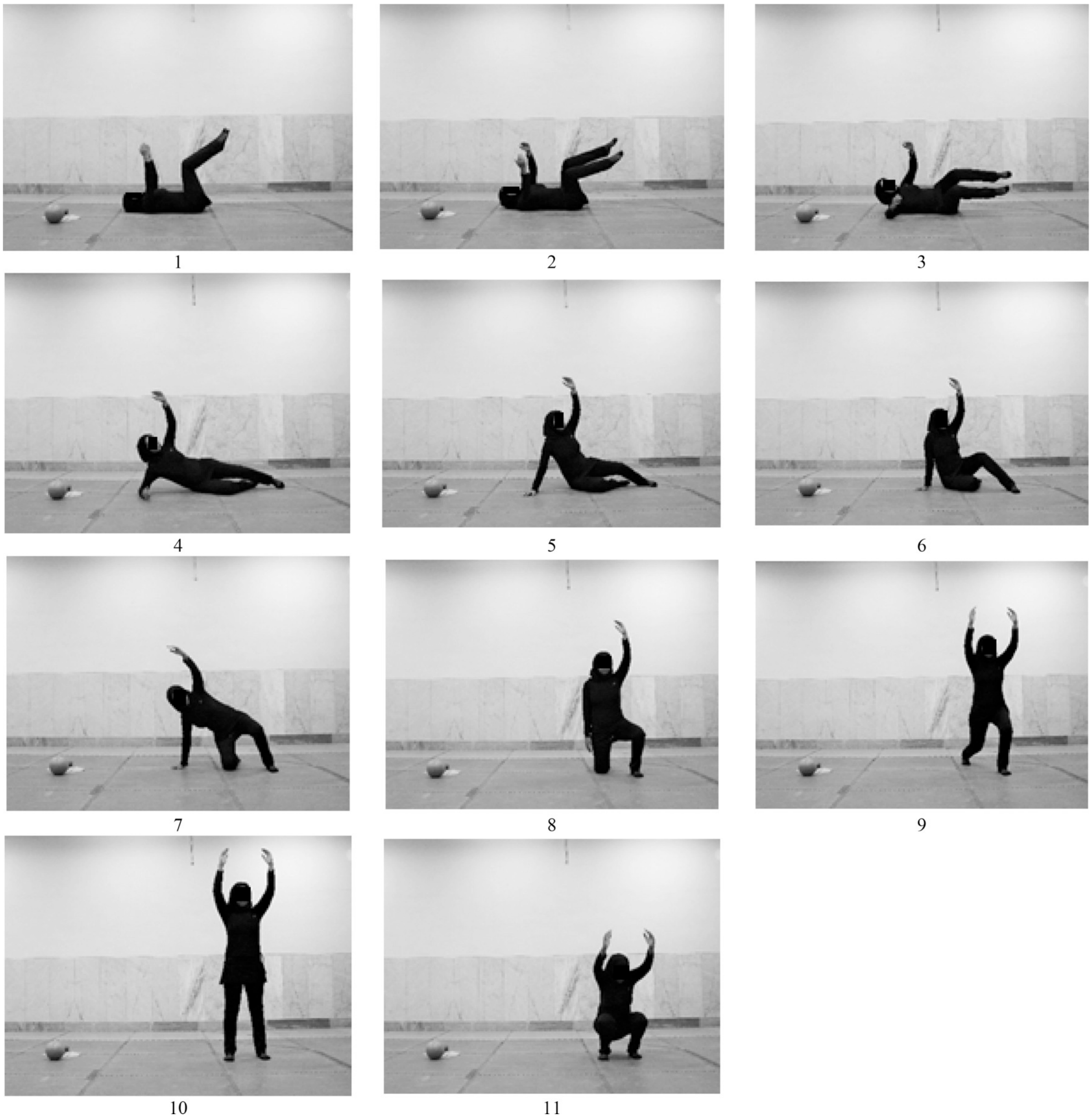

Tripod


Kneeling


Squat


Prone

Appendix D. Eleven phases of Czech Get Up Movement



References

Ageberg, E., Bennell, K. L., Hunt, M. A., Simic, M., Roos, E. M., & Creaby, M. W. (2010). Validity and inter-rater reliability of medio-lateral knee motion observed during a single-limb mini squat. *BMC Musculoskeletal Disorders, 11*(1), 265.

Bardenett, S. M., Micca, J. J., DeNoyelles, J. T., Miller, S. D., Jenk, D. T., & Brooks, G. S. (2015). Functional Movement Screen normative values and validity in high school athletes: Can the FMS be used as a predictor of injury? *International Journal of Sports Physical Therapy, 10*(3), 303.

Bell, D. R., Oates, D. C., Clark, M. A., & Padua, D. A. (2013). Two-and 3-dimensional knee valgus are reduced after an exercise intervention in young adults with demonstrable valgus during squatting. *Journal of Athletic Training, 48*(4), 442–449.

Bell, D. R., Smith, M. D., Pennuto, A. P., Stiffler, M. R., & Olson, M. E. (2014). Jump-landing mechanics after anterior cruciate ligament reconstruction: A landing error scoring system study. *Journal of Athletic Training, 49*(4), 435–441.

Boden, B. P., Dean, G. S., Feagin, J. A., & Garrett, W. E. (2000). Mechanisms of anterior cruciate ligament injury. *Orthopedics, 23*(6), 573–578.

Bokarius, V. (2008). Long-term efficacy of dynamic neuromuscular stabilization in treatment of chronic musculoskeletal pain. *Age, 18*(25), 3.

Bonazza, N. A., Smuin, D., Onks, C. A., Silvis, M. L., & Dhawan, A. (2017). Reliability, validity, and injury predictive value of the functional movement screen: A systematic review and meta-analysis. *The American Journal of Sports Medicine, 45*(3), 725–732.

Chapman, R. F., Laymon, A. S., & Arnold, T. (2014). Functional movement scores and longitudinal performance outcomes in elite track and field athletes. *International*

Journal of Sports Physiology & Performance, 9(2).
Chimera, N. J., Smith, C. A., & Warren, M. (2015). Injury history, sex, and performance on the functional movement screen and Y balance test. *Journal of Athletic Training, 50*(5), 475–485.
Chorba, R. S., Chorba, D. J., Bouillon, L. E., Overmyer, C. A., & Landis, J. A. (2010). Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *North American Journal of Sports Physical Therapy, 5*(2), 47.
Clark, M., & Lucett, S. (2010). *NASM essentials of corrective exercise training.* Lippincott Williams & Wilkins.
Cook, G., Burton, L., Kiesel, K., Bryant, M., & Torine, J. (2010). *Movement: Functional movement systems: screening, assessment, and corrective strategies. vol. 24*. On Target Publications Aptos, CA.
De Loes, M. (1995). Epidemiology of sports injuries in the Swiss organization. *International Journal of Sports Medicine, 16*(2), 134–138.
Deli, E., Bakle, I., & Zachopoulou, E. (2006). Implementing intervention movement programs for kindergarten children. *Journal of Early Childhood Research, 4*(1), 5–18.
Elphinston, J., & Hardman, S. L. (2006). Effect of an integrated functional stability program on injury rates in an international netball squad. *Journal of Science and Medicine in Sport, 9*(1), 169–176.
Field, A. P. (2005). *Eta and eta squared.* Wiley StatsRef: Statistics Reference Online.
Frank, C., Kobesova, A., & Kolar, P. (2013). Dynamic neuromuscular stabilization & sports rehabilitation. *International Journal of Sports Physical Therapy, 8*(1), 62.
Frost, D. M., Beach, T. A. C., Callaghan, J. P., & McGill, S. M. (2012). Using the functional movement screening to evaluate the effectiveness of training. *The Journal of Strength & Conditioning Research, 26*(6), 1620–1630.
Hammes, D., Aus der Funten, K., Bizzini, M., & Meyer, T. (2016). Injury prediction in veteran football players using the functional movement screen. *Journal of Sports Sciences, 34*(14), 1371–1379.
Harris, B. A., & Dyrek, D. A. (1989). A model of orthopaedic dysfunction for clinical decision making in physical therapy practice. *Physical Therapy, 69*(7), 548–553.
Jafari, M., Zolaktaf, V., & Ghasemi, G. (2020). Functional movement screen composite scores in firefighters: Effects of corrective exercise training. *Journal of Sport Rehabilitation, 29*, 102–106.
Juehring, D. D., & Barber, M. R. (2011). A case study utilizing Vojta/dynamic neuromuscular stabilization therapy to control symptoms of a chronic migraine sufferer. *Journal of Bodywork and Movement Therapies, 15*(4), 538–541.
Kiesel, K., Plisky, P., & Butler, R. (2011). Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scandinavian Journal of Medicine & Science in Sports, 21*(2), 287–292.
Kiesel, K., Plisky, P. J., & Voight, M. L. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen. *N Am J Sports Phys Ther, 2*(3), 147–158.
Kobesova, A., Dzvonik, J., Kolar, P., Sardina, A., & Andel, R. (2015). Effects of shoulder girdle dynamic stabilization exercise on hand muscle strength. *Isokinetics and Exercise Science, 23*(1), 21–32.
Kolar, P., & Kobesova, A. (2010). Postural-locomotion function in the diagnosis and treatment of movement disorders. *Clinical Chiropractic, 13*(1), 58–68.
Kraus, K., Schutz, E., Taylor, W. R., & Doyscher, R. (2014). Efficacy of the functional movement screen: A review. *The Journal of Strength & Conditioning Research, 28*(12), 3571–3584.
Lantinga, S. B. (2013). Born to run: A hidden tribe, superathletes, and the greatest race the world has never seen (book review). *Pro Rege, 41*(3), 31–33.
Letafatkar, A., Hadadnezhad, M., Shojaedin, S., & Mohamadi, E. (2014). Relationship between functional movement screening score and history of injury. *International Journal of Sports Physical Therapy, 9*(1), 21.
Louw, Q. A., Manilall, J., & Grimmer, K. A. (2008). Epidemiology of knee injuries among adolescents: A systematic review. *British Journal of Sports Medicine, 42*(1), 2–10.
O Connor, F. G., Deuster, P. A., Davis, J., Pappas, C. G., & Knapik, J. J. (2011). Functional movement screening: Predicting injuries in officer candidates. *Medicine and Science in Sports and Exercise, 43*(12), 2224–2230.
Oliver, J. L., Lloyd, R. S., & Meyers, R. W. (2011). Training elite child athletes: Promoting welfare and well-being. *Strength & Conditioning Journal, 33*(4), 73–79.
Oppelt, M., Juehring, D., Sorgenfrey, G., Harvey, P. J., & Larkin-Thier, S. M. (2014). A case study utilizing spinal manipulation and dynamic neuromuscular stabilization care to enhance function of a post cerebrovascular accident patient. *Journal of Bodywork and Movement Therapies, 18*(1), 17–22.
Padua, D. A., Boling, M. C., DiStefano, L. J., Onate, J. A., Beutler, A. I., & Marshall, S. W. (2011). Reliability of the landing error scoring system-real time, a clinical assessment tool of jump-landing biomechanics. *Journal of Sport Rehabilitation, 20*(2), 145–156.
Padua, D. A., DiStefano, L. J., Beutler, A. I., De La Motte, S. J., DiStefano, M. J., & Marshall, S. W. (2015). The landing error scoring system as a screening tool for an anterior cruciate ligament injury-prevention program in elite-youth soccer athletes. *Journal of Athletic Training, 50*(6), 589–595.
Padua, D. A., Marshall, S. W., Boling, M. C., Thigpen, C. A., Garrett, W. E., Jr., & Beutler, A. I. (2009). The landing error scoring system (LESS) is a valid and reliable clinical assessment tool of jump-landing biomechanics: The JUMP-ACL study. *The American Journal of Sports Medicine, 37*(10), 1996–2002.
Patel, D. R., & Nelson, T. L. (2000). Sports injuries in adolescents. *Medical Clinics, 84*(4), 983–1007.
Phillips, A. (2012). *Dynamic Neuromuscular Stabilization, Sport I: Review and Recap.* pikeathletics.com, from pikeathletics.com.
Pierce, C. A., Block, R. A., & Aguinis, H. (2004). Cautionary note on reporting eta-squared values from multifactor ANOVA designs. *Educational and Psychological Measurement, 64*(6), 916–924.
Plisky, P. J., Gorman, P. P., Butler, R. J., Kiesel, K. B., Underwood, F. B., & Elkins, B. (2009). The reliability of an instrumented device for measuring components of the star excursion balance test. *North American journal of sports physical therapy: NAJSPT, 4*(2), 92.
Rose, S. J. (1986). Description and classification-the cornerstones of pathokinesiological research. *Physical Therapy, 66*(3), 379–381.
Sahrmann, S. (2002). *Diagnosis and treatment of movement impairment syndromes.* Elsevier Health Sciences.
Santana, J. C. (2016). *Functional training: Human kinetics*.
Shaffer, S. W., Teyhen, D. S., Lorenson, C. L., Warren, R. L., Koreerat, C. M., Straseske, C. A., & Childs, J. D. (2013). Y-balance test: A reliability study involving multiple raters. *Military Medicine, 178*(11), 1264–1270.
Sullivan, L. (2016). *Power and sample size determination.* Boston University School of Public Health. In.
Ugalde, V., Brockman, C., Bailowitz, Z., & Pollard, C. D. (2015). Single leg squat test and its relationship to dynamic knee valgus and injury risk screening. *PM&R, 7*(3), 229–235.
Warren, M., Lininger, M., Chimera, N., J., & Smith, C., A. (2018). Utility of FMS to understand injury incidence in sports: current perspectives. *Open Access Journal of Sports Medicine,* (9), 171–182.
Warren, M., Smith, C. A., & Chimera, N. J. (2015). Association of the Functional Movement Screen with injuries in division I athletes. *Journal of Sport Rehabilitation, 24*(2).
Wickens, C. D. (1991). *Processing resources and attention. Multiple-task performance. 1991*, 3–34.
Wieczorkowski, M. P. (2010). *Functional movement screening as a predictor of injury in high school basketball athletes*.
Wright, M. D., Portas, M. D., Evans, V. J., & Weston, M. (2015). The effectiveness of 4 weeks of fundamental movement training on functional movement screen and physiological performance in physically active children. *The Journal of Strength & Conditioning Research, 29*(1), 254–261.
Yoon, H. S., & You, J. S. H. (2017). Reflex-mediated dynamic neuromuscular stabilization in stroke patients: EMG processing and ultrasound imaging. *Technology and Health Care (Preprint),* 1–8.