The Effects of a Novel Quadrupedal Movement Training Program on Functional Movement, Range of Motion, Muscular Strength, and Endurance

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Abstract

Buxton, JD, Prins, PJ, Miller, MG, Moreno, A, Welton, GL, Atwell, AD, Talampas, TR, and Elsey, GE. The effects of a novel quadrupedal movement training program on functional movement, range of motion, muscular strength, and endurance. *J Strength Cond Res* XX(X): 000–000, 2020—Quadrupedal movement training (QMT) is a form of bodyweight training incorporating animal poses, transitions, and crawling patterns to reportedly improve fitness. This type of training may improve multiple facets of fitness, unfortunately, little evidence exists to support commercial claims and guide practitioners in the best use of QMT. Therefore, the purpose of this study was to assess the impact of a commercially available QMT program on functional movement, dynamic balance, range of motion, and upper body strength and endurance. Forty-two active college-age (19.76 ± 2.10 years) subjects (males = 19, females = 23) were randomly assigned to a QMT ($n = 21$) or control (CON) ($n = 21$) group for 8 weeks. Quadrupedal movement training consisted of 60-minute classes performed $2\times\cdot wk^{-1}$ in addition to regular physical activity. Active range of motion, Functional Movement Screen (FMS), Y-Balance Test (YBT), handgrip strength, and push-up endurance were assessed before and after the intervention. The QMT group showed significantly greater improvements than the CON group in FMS composite score (1.62 ± 1.53 vs. 0.33 ± 1.15, $p = 0.004$) and FMS advanced movements (0.81 ± 0.87 vs. 0.01 ± 0.71, $p = 0.002$) and fundamental stability (0.57 ± 0.75 vs. 0.05 ± 0.50, $p = 0.011$), along with hip flexion, hip lateral rotation, and shoulder extension ($p < 0.05$). No significant differences between groups were observed for dynamic balance or upper body strength and endurance. Our results indicate that QMT can improve FMS scores and various active joint ranges of motion. Quadrupedal movement training is a viable alternative form of training to improve whole-body stabilization and flexibility.

Key Words: quadrupedal locomotion, flexibility, motor control, FMS, mobility

Introduction

Quadrupedal movement training (QMT) is an emerging style of bodyweight training that is gaining popularity in the fitness industry. Quadrupedal movement training incorporates postures and movements mimicking the neurodevelopmental sequence (25) and animal postures and movements (e.g., crawling, rolling, postural transitions, etc). Many elements of QMT (e.g., quadrupedal alternating limb lift and 4-point crawling) are used in physical rehabilitation of injuries and neurological diseases (9,21,28,46). Recently, quadrupedal movements have become popular additions to fitness programs as part of a dynamic warmup or as accessory exercises (18,44).

Currently, several commercially available QMT systems exist including, Ground Force Method, Ginastica Natural, Original Strength, MovNat, and Animal Flow (AF). AF is a novel form of QMT consisting of dynamic quadrupedal movements that are practiced, sequenced with other movements, and eventually choreographed into a flow (a series of AF movements linked together). Like other commercial QMT systems, the AF system claims to improve flexibility, range of motion, strength, and endurance; however these claims have not been substantiated.

Recently, research showed that QMT, specifically the quadrupedal crawling exercises used in AF, improved cognitive skills and joint reposition sense (33). Furthermore, greater EMG activity of core muscles was noticed in quadrupedal movements involving cross-crawling patterns similar to those practiced in most QMT systems (40). The aforementioned studies suggest that QMT may improve proprioception and core stability, which have been linked to improvements in both functional movement and fitness (20). Additional research investigating similar training strategies such as yoga (10), Pilates (30), and Dynamic Neuromuscular Stabilization (26) have shown improvements in upper body muscular endurance, flexibility, and grip strength.

This evidence suggests that QMT may improve performance of basic movement patterns and other fitness components such as upper body muscular endurance, strength, flexibility, and dynamic balance. We hypothesized that QMT would produce significantly greater improvements in each of these outcomes than a

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comparable physically active control group not performing QMT. Such findings would be appealing for fitness specialists because it could show an alternative and novel training program to be effective for enhancing these elements of fitness above and beyond that of regular training. Currently, no empirical evidence exists to support these conclusions, nor have any studies investigated the impact of AF, or any QMT program, on these fitness elements. Thus, the purpose of this study is to assess the effects of a novel eight-week progressive QMT program, using the AF system, on functional movement, dynamic balance, range of motion, and muscular strength and endurance.

Methods

Experimental Approach to the Problem

This study used a randomly assigned parallel groups design involving an intervention (QMT) and a control group (CON). Both groups maintained their normal physical fitness regimens for 8 weeks, whereas the intervention group participated in 2 additional 60-minute QMT sessions per week. All subjects performed range of motion assessment, Functional Movement Screen (FMS), Y-Balance Test (YBT), handgrip strength (HGS) test, and push-up endurance test before and after the 8-week intervention period. All familiarization, testing, and QMT training sessions were conducted in the Exercise Science Laboratory and Dance Studios located in the Physical Learning Center building at Grove City College.

Subjects

A convenience sample of 44 (19 male and 25 female; No subject was under age of 18) physically active (30 minutes of moderate intensity structured activity, 3 $d \cdot wk^{-1}$ for at least 3 months) (41) college students without any physical limitations or history of advanced training methods such as yoga, Pilates, CrossFit, Olympic lifting, etc. volunteered for this study. Two subjects withdrew because of scheduling conflicts midway through the study leaving 19 men and 23 women ($n = 42$) for final analysis. Our sample size of 30–40 subjects was calculated using G*Power version 3.1.9.2 with a probability of error set at 0.05, power at 0.80 and moderate-to-large effect sizes. Subject demographics are provided in Table 1.

The experimental protocols were approved by the Institutional Review Boards of Rocky Mountain University of Health Professions and Grove City College. All subjects were informed of the risks and potential discomforts associated with testing and the intervention before providing their written informed consent. A familiarization session consisting of several practice trials of each test was provided to minimize learning effects. Subjects were instructed to refrain from caffeine and alcohol consumption for 48 hours, physical activity for 24 hours and any food and drink for 3 hours before each testing session. After pretesting, subjects were then assigned to either the QMT or control CON group using a random number generator (www.randomizer.org). Both groups were instructed to maintain their usual training frequency and activities throughout the study without increasing or decreasing training load. Compliance to this instruction was assessed using a physical activity log during the first and last week of the intervention. In addition, subjects were instructed to refrain from using any ergogenic aids and to maintain their regular dietary habits throughout the study.

Table 1

Subject demographics, physical activity (PA) log data (means ± *SD*) and *p*-value for independent samples t tests of baseline characteristics.*

	QMT ($n = 21$)	CON ($n = 21$)	*p*
Age	19.38 ± 1.36	20.14 ± 2.63	0.236
Height (cm)	174.64 ± 13.05	173.32 ± 10.53	0.915
Mass (kg)	68.87 ± 11.80	66.55 ± 11.64	0.715
Body fat %	20.29 ± 7.04	19.99 ± 6.56	0.691
Fat Mass (kg)	13.51 ± 4.00	13.20 ± 4.66	0.822
Fat free Mass (kg)	55.36 ± 13.03	54.34 ± 10.96	0.589
PA wk 1 ($min \cdot wk^{-1}$)	385.71 ± 164.26	355.05 ± 223.27	0.615
PA wk 8 ($min \cdot wk^{-1}$)	388.19 ± 167.59	381.52 ± 296.14	0.929

*QMT = ground-based movement training group; CON = control group.

Procedures

Training Intervention. Subjects in both the QMT and CON group maintained their regular physical activity regimens, which consisted of a combination of general aerobic, free weight/machine-based resistance training, and static stretching, throughout the eight-week intervention period. Subjects in the QMT group participated in 2 additional 60-minute QMT sessions per week separated by a minimum of 48 hours between sessions (16 total sessions). All QMT sessions were group formats based on the AF system and led by the principle investigator (Animal Flow Level 1 Instructor certified).

During the first 4 weeks, each QMT session began with general dynamic stretches followed by specific wrist mobility exercises, core and shoulder activation exercises, form specific stretches, traveling forms, switches and transitions, and finally, choreographed flows (Table 2). Sessions during the last 4 weeks began with general dynamic stretches, wrist mobility exercises, and form-specific stretches. This was followed by one to 2 mini circuits consisting of an activation exercise, a form specific stretch and a traveling form performed for 30–60 seconds. The circuits were followed by combinations of switches and transitions and, finally, a choregraphed flow segment (Table 2). Progressive overload was applied throughout the intervention period by gradually increasing reps and sets of each movement, and by gradually decreasing rest times between sets and exercises.

Data Collection. During the initial familiarization session, height (cm) measurements were taken using a physician's scale (Pelstar; LLC/Health O Meter Professional Scales, McCook, IL) followed by body composition analysis (mass [kg], fat mass [% and kg] and fat-free mass [kg]) using a Tanita bioelectrical impedance analyzer (MC-980Plus; Tanita Corporation of America, Arlington Heights, IL). Subjects then practiced several trials of the range of motion assessments, FMS, YBT, handgrip dynamometer, and pushup test.

The schedule for pretesting and post-testing was identical: (a) active joint ROM, (b) functional movement, (c) dynamic balance, (d) muscular strength, and (e) upper body muscular endurance.

Active Joint Range of Motion. Active range of motion for ankle dorsiflexion, hip flexion, hip extension, hip medial and lateral rotation, shoulder flexion, shoulder extension and shoulder medial, and lateral rotation were assessed using a standard goniometer (True Angle; Quint Graphics, Columbus, NJ). Procedures for evaluating each joint motion followed previously established guidelines (19). Degrees of motion were assessed to the nearest

Table 2
Sample Animal Flow (AF) training programs.

AF categories	AF movements	Reps/Time	Sets	Rest
Sample AF training session for weeks 1–4				
Wrist mobilizations	Wrist rolls	30 s each	1	0
	Wrist waves	30 s each	1	0
	Prayer stretch	30 s	1	0
	Wrist shakers	30 s	1	0
	Wrist relief	30 s	1	0
	Quadruped wrist	60 s	1	0
Activations	Beast 1	10–15 s	2	30–60 s
	Crab 1	10–15 s	2	30–60 s
	Beast 2	10–15 s	2	30–60 s
	Crab 2	10–15 s	2	30–60 s
Form stretches	Loaded beast unload	3 to 5	1	30–60 s
	Loaded beast wave	2 to 3	1	30–60 s
	Ape reach	3 to 5	1	30–60 s
Traveling forms	Forward/reverse beast	10 yds	1 to 3	30–60 s
	Forward/reverse Ape	10 yds	1 to 3	30–60 s
Switches & transitions	Underswitch	10 to 20	1 to 3	30–60 s
	Side kick through	10 to 20	1 to 3	30–60 s
Flows/Games	Use movements taught earlier in class and from previous classes	60–90 s	1 to 5	60–120 s
Sample AF training session for weeks 5–8				
Wrist mobilizations	Wrist rolls	30 s	1	0
	Wrist waves	30 s	1	0
	Prayer stretch	30 s	1	0
	Wrist shakers	30 s	1	0
	Wrist relief	30 s	1	0
	Quadruped wrist	30 s	1	0
Form stretches flow	Perform as a circuit 2× through			
	Loaded beast unload	1	2	0
	Wave unload	1	2	0
	Beast reach	1	2	0
	Ape reach	2	2	0
AMM circuit 1	Perform as a circuit 3× with 30–60 s rest b/w circuits			
Activate	Beast 3	10	3	15 s
Mobilize	Crab reach	10	3	15 s
Move	Lateral Ape 1	10	3	15 s
AMM circuit 2	Perform as a circuit 3× with 30–60 s rest b/w circuits			
Activate	Crab 3	10	3	15 s
Mobilize	Scorpion reach	6	3	15 s
Move	Forward/reverse beast	20 (10 each)	3	15 s
Switches and transitions	Perform all sets of combo 1 then perform all sets of combo 2			
Combo 1	Side kick through to full scorpion	5–10 per side	2 to 3	60 s
Combo 2	Front step though to front kick through	5–10 per side	2 to 3	60 s
Flows	Beast flow 1	2–4 rounds		60 s

0.5°. Three measurements were taken on both right and left sides for each motion with the averages for each side used for analysis. Before testing an intrarater reliability of $r = 0.99$ was established for the principle investigator.

Functional Movement. Functional movement was assessed using the FMS. The FMS is a screening tool used to assess performance of a series of fundamental movement patterns. The FMS consists of 7 individual movement patterns and 3 clearing tests. Each of these 7 tasks can be categorized into 1 of 3 subcategories: advanced movements (Deep Squat, Hurdle Step & In-Line Lunge), fundamental mobility (Shoulder Mobility and Active Straight Leg Raise), and fundamental stability (Trunk Stability Push-up and Rotary Stability Test) (9,27,43). Performance of the 7 movements was scored on an ordinal scale of "0–3," where "3" represents completion of the movement without compensation, "2" represents completion of the movement with compensation, "1" represents an inability to complete the movement, and "0" represents pain during either the movement or associated clearing test (3). Five of the 7 tests assess right and left side separately with the lowest of the 2 scores being used to compute a final score for each of these 5 tests. All final scores were summed to compute an overall composite score (CS). In addition, CSs were computed for each FMS sub-category (43). The FMS Test Kit (Functional Movement Systems, Inc., Chatham, Virginia) was used to administer the test. Testing procedures followed the guidelines established by Cook, et al. (6–8). The FMS shows good reliability ($r = 0.81–0.91$) and face validity for assessing functional movement, however, content and construct validity remain unclear (3).

Dynamic Balance. Dynamic balance was assessed using the YBT, which measures the farthest single limb reach attained in 3 reaching directions while balancing on a platform with the opposite limb (3,39). Procedures for upper quarter (UQ) and lower quarter (LQ) tests followed previously established guidelines (15,39). The YBT kit (Functional Movement Systems Inc.) was used to administer the test. The farthest reach in each of the 3 reaching directions to the nearest 0.50 cm was recorded and used to determine a normalized (by subject's lower and upper extremity length) CS and normalized single reach scores for each reach direction. The YBT has good intrarater reliability (r = 0.84–0.91) and good content and face validity (3).

Muscular Strength. Muscular strength was assessed via a HGS test using a TKK Smedley III Analog Grip Tester (Takei Scientific Instruments Co., Ltd., Niigata City, Japan). Handgrip strength testing is one of the most valid and reliable field measures of muscular strength and fitness (3). Subjects stood erect with their shoulder adducted and neutrally rotated (along the side of the body), elbow extended and forearm, wrist and hand in a neutral position. Subjects were then instructed to squeeze the dynamometer with one maximal effort (no more than 5 seconds) and no extraneous movement (36). Three trials were administered for each hand with 1-minute rest between trials. Each trial was measured to the nearest 0.50 kg with the best score achieved for each hand used for data analysis.

Upper Body Muscular Endurance. A push-up test following guidelines established by the ACSM (38) and NSCA (16) was used to assess upper body muscular endurance. Male subjects used a standard push-up position and females used a modified push-up position with knees on the ground. Subjects were instructed to perform as many consecutive repetitions as possible without rest. Tests were terminated when subjects could no longer maintain proper technique within 2 repetitions or rested for more than 2 seconds in the up position. The total number of push-ups was recorded and used for analysis.

Statistical Analyses

Statistical analyses were performed using SPSS version 23.0 (IBM SPSS Statistics Inc., Chicago, IL). Statistical significance was set a priori at $p < 0.05$. Descriptive statistics were calculated for all variables. An independent samples t-test was used to assess baseline differences between groups.

A 2 (pre vs post) × 2 (QMT vs. CON) mixed analysis of variance (ANOVA) with repeated measures for time was performed to assess differences between groups over the 8-week intervention period. Post-hoc analyses of significant main and interaction effects were conducted where appropriate using the Bonferroni adjustment. The assumption of sphericity was confirmed using Mauchly's test. Greenhouse-Geisser epsilon corrections were used when the assumption of sphericity was violated. Effect sizes using partial eta squared (η_p^2) (small = 0.01, medium = 0.06, & large = 0.14) (29) and 95% confidence intervals (CIs) were calculated.

Results

Baseline Differences, Session Attendance, and Physical Activity

Independent samples t tests revealed no significant differences between groups at baseline for any demographic or outcome variables ($p > 0.05$). Quadrupedal movement training session attendance was 94% with subjects attending an average of 15.10 ± 0.99 of 16 training sessions over the intervention period. Finally, 2 × 2 mixed ANOVA showed no group × time interaction (p = 0.551), or main effects for time (p = 0.473) or group (p = 0.774), indicating that both groups' amount of physical activity were similar throughout the intervention.

Range of Motion

Means and standard deviations for each ROM test are shown in Table 3. Significant group × time interactions were found for right shoulder extension ($p = 0.004$, $\eta_p^2 = 0.189$), left shoulder extension ($p = 0.008$, $\eta_p^2 = 0.163$), left hip extension ($p = 0.033$, $\eta_p^2 = 0.109$), right hip flexion ($p = 0.002$, $\eta_p^2 = 0.218$), left hip flexion ($p = 0.004$, $\eta_p^2 = 0.192$), right hip lateral rotation ($p = 0.002$, $\eta_p^2 = 0.209$), and left hip lateral rotation ($p = 0.013$, $\eta_p^2 = 0.131$) with the QMT group showing a significantly greater average increase in active ROM over time than the CON group. In addition, QMT significantly improved right shoulder lateral rotation ($p = 0.029$), right hip extension ($p = 0.005$), right and left medial hip rotation ($p < 0.001$ & $p = 0.001$), and right and left ankle dorsiflexion ($p = 0.018$ & $p = 0.002$) pretest to post-test; however these changes were not significantly different than the CON.

Functional Movement

Table 4 presents the means and standard deviations for the FMS results and the YBT, handgrip, and pushup tests. Functional Movement Screen CSs (FMSCS) improved significantly more across time in the QMT group than the CON group ($p = 0.004$, $\eta_p^2 = 0.191$) (Figure 1A). The QMT group improved FMSCS an average of 1.62 ± 1.53 ($p < 0.001$, 95% CI 0.93–2.31) points, whereas there was no significant improvement in CON group ($p = 0.267$).

Functional Movement Screen Subanalysis

There was a significant group × time interaction for advanced movement CSs (AM) ($p = 0.002$, $\eta_p^2 = 0.214$) showing that the QMT group improved average scores more over time than the CON (Figure 1B). The average change pretest to post-test for the QMT group was 0.81 ± 0.87 ($p < 0.001$, 95% CI 0.41–1.21) points. No significant change in AM was found for the CON group ($p = 1.00$).

In addition, a significant group × time interaction was found for fundamental stability CSs (STAB) ($p = 0.011$, $\eta_p^2 = 0.152$), with the QMT group's average scores improving more over time than the CON (Figure 1D). The QMT group showed a significant average improvement of 0.57 ± 0.75 ($p = 0.002$, 95% CI 0.25–0.90) points. No significant change was found for the CON group ($p = 0.733$). There was no significant group × time interaction for fundamental mobility CSs (MOB) ($p = 0.843$); however, a significant main effect for time ($p = 0.035$, $\eta_p^2 = 0.107$) showed that both groups improved pretest to post-test. In addition, a significant main effect for group ($p = 0.008$, $\eta R_p RP^2 = 0.161$) revealed that QMT had higher MOB scores at both pretest and post-test compared with CON.

Dynamic Balance

There were no significant differences in YBT UQ and LQ right and left CSs between groups over the course of the intervention (UQ: $p = 0.154$ & 0.063, LQ: $p = 0.167$ & 0.265 respectively).

Table 3
Means and *SD*s for Range of Motion (in degrees).*†

	QMTpretest	QMTpost-test	CONpretest	CONpost-test
R hip ext	21.27 ± 5.96	25.67 ± 8.44†	22.94 ± 6.91	24.21 ± 7.61†
L hip ext	21.98 ± 5.80	26.47 ± 7.82§	23.63 ± 7.76	23.02 ± 9.06
R shoulder ext	33.13 ± 12.64	37.29 ± 10.99§	37.83 ± 12.57	33.60 ± 10.62
L shoulder ext	30.90 ± 12.11	37.98 ± 10.93§	34.31 ± 13.47	32.19 ± 11.32
R hip flexion	118.42 ± 5.73	127.45 ± 6.43§	118.34 ± 10.13	121.23 ± 10.92
L hip flexion	120.35 ± 7.93	127.41 ± 8.41§	119.95 ± 9.92	121.06 ± 10.92
R shoulder flex	179.12 ± 2.84‖	179.51 ± 1.66‖	174.56 ± 6.61	174.29 ± 7.95
L shoulder flex	178.52 ± 3.82‖	178.95 ± 2.94‖	175.40 ± 7.47	174.31 ± 8.60
R shoulder MR	63.88 ± 16.25	64.18 ± 15.91	56.91 ± 15.31	55.24 ± 13.20
L shoulder MR	71.56 ± 16.89‖	71.95 ± 15.54‖	63.28 ± 13.72	61.87 ± 15.08
R shoulder LR	96.36 ± 8.88	101.93 ± 10.18†	94.50 ± 15.73	99.47 ± 13.90†
L shoulder LR	91.48 ± 9.63	95.13 ± 8.28†	88.17 ± 11.85	92.21 ± 14.09†
R hip MR	36.51 ± 7.10	42.25 ± 8.31†	36.97 ± 5.23	40.29 ± 7.45†
L hip MR	34.77 ± 6.56	39.45 ± 8.74†	37.67 ± 5.13	39.60 ± 7.13†
R hip LR	30.02 ± 6.66	36.29 ± 9.79§	32.65 ± 6.89	32.55 ± 7.50
L hip LR	33.33 ± 5.93	38.42 ± 6.94§	33.21 ± 6.68	32.90 ± 7.09
R ankle DF	19.63 ± 5.56	22.17 ± 5.44‡	17.83 ± 5.35	19.69 ± 5.09‡
L ankle DF	19.86 ± 5.62	22.79 ± 6.08‡	18.55 ± 5.80	19.57 ± 4.75‡

*Ext/Flex = extension/flexion, MR/LR = medial rotation/lateral rotation, DF = dorsiflexion.
†QMT $n = 21$, CON $n = 21$.
‡Significant main effect for time ($p < 0.05$), post-test > than pre-test for both QMT and CON.
§Significant group by time interaction ($p < 0.05$), QMT > improvement over time than CON.
‖Significant main effect for group ($p < 0.05$), QMT > than CON at pretest and post-test.

The QMT group significantly increased YBT UQ right CS by 5.17 ± 6.96% ($p < 0.001$, 95% CI 2.61–7.73%), UQ left by 4.70 ± 6.92% ($p = 0.003$, 95% CI 1.65–7.76%), LQ right by 2.24 ± 4.79% ($p = 0.015$, 95% CI 0.46–4.02%), and LQ left by 2.11 ± 2.20% ($p < 0.001$, 95% CI 1.03–3.20%). The CON group significantly increased UQ right by 2.57 ± 4.37% ($p = 0.049$, 95% CI 0.01–5.13%) and LQ left by 1.26 ± 2.69% ($p = 0.024$, 95% CI 0.17–2.34%).

There was a significant interaction between group and time for YBT LQ right posterolateral reach scores ($p = 0.02$, $\eta_p^2 = 0.127$) showing that the GBMT group improved significantly more over time than the CON group. The QMT group significantly improved YBT UQ right and left medial reach ($p = 0.004$ & 0.042 respectively), UQ left superolateral reach ($p = 0.004$), LQ right and left posteromedial reach ($p = 0.027$ and 0.009 respectively), and LQ right and left posterolateral reach ($p = 0.005$ and 0.019 respectively) scores pre-intervention to postintervention; however, these improvements were not significantly different than the CON group. There were no significant improvements pre-to post-intervention for any single direction reach score in the CON group.

Upper Body Muscular Strength and Endurance

There were no significant interaction effects or main effects ($p > 0.05$) for either right or left HGS. Additionally, there were no significant interaction effect ($p = 0.427$) or main effect for group ($p = 0.744$) with regards to push-up endurance. However, a significant main effect for time ($p < 0.001$, $\eta_p^2 = 0.506$) showed that the average number of push-ups increased over time

Table 4
Means and *SD*'s pretest and post-test for FMS, Y-Balance, Push-ups, and Handgrip.*†

	QMTpretest	QMTpost-test	CONpretest	CONpost-test
FMSCS	13.76 ± 1.33	15.38 ± 1.91‡	13.29 ± 1.95	13.61 ± 2.13
AM	5.52 ± 0.98	6.33 ± 1.15‡	5.95 ± 1.02	5.95 ± 1.02
MOB	5.05 ± 0.92§	5.29 ± 0.78§‖	4.14 ± 1.35	4.43 ± 1.25‖
STAB	3.19 ± 0.40	3.76 ± 0.94‡	3.19 ± 0.51	3.24 ± 0.70
YBT UQRCS	96.01 ± 8.62	101.18 ± 10.51‖	96.79 ± 8.29	99.36 ± 9.27‖
YBT UQLCS	96.16 ± 9.05	100.86 ± 10.05‡	99.61 ± 6.89	100.24 ± 8.62
YBT LQRCS	91.89 ± 6.83	94.14 ± 6.21‖	94.62 ± 5.71	95.10 ± 6.55‖
YBT LQLCS	91.54 ± 8.50	93.65 ± 7.82‖	93.75 ± 7.72	95.01 ± 6.76‖
Push-ups	25.05 ± 14.07	31.57 ± 14.99‖	24.48 ± 11.79	29.52 ± 11.86‖
Handgrip right (kg)	37.50 ± 12.58	38.38 ± 12.12	38.80 ± 11.82	38.81 ± 11.50
Handgrip left (kg)	34.29 ± 12.05	35.21 ± 12.13	34.98 ± 10.14	36.05 ± 11.08

*FMSCS = functional movement screen composite score; AM = functional movement subcategory composite score; MOB = fundamental mobility subcategory composite score; STAB = fundamental stability subcategory composite score; YBT UQRCS/UQLCS = Y-Balance Test upper quarter right/left composite score; YBT LQRCS/LQLCS = Y-Balance Test lower quarter right/left composite score.
†QMT $n = 21$, CON $n = 21$.
‡Significant group by time interaction ($p < 0.05$), QMT > improvement over time than CON.
§Significant main effect for group ($p < 0.05$), QMT > than CON at pretest and post-test.
‖Significant main effect for time ($p < 0.05$), post-test > than pre-test for both QMT and CON.

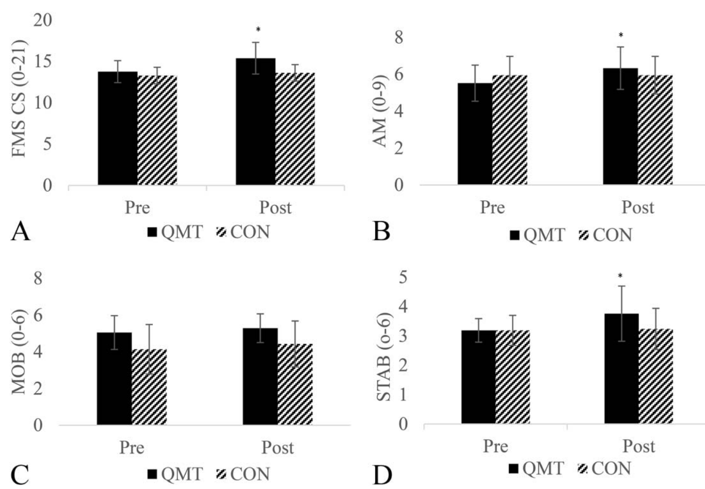

Figure 1. A) Functional movement screen, (B) advanced movement (AM), (C) fundamental mobility (MOB), and (D) fundamental stability (STAB) composite scores pre-intervention and postintervention. *QMT significantly greater pre-intervention to postintervention and significantly greater change across time than CON. QMT = ground-based movement training group; CON = control group.

regardless of group. The QMT group increased number of push-ups on average by 6.52 ± 5.52 ($p < 0.001$, 95% CI 3.89–9.15), whereas those in the CON group improved by 5.05 ± 6.38 ($p < 0.001$, 95% CI 2.42–7.68).

Discussion

To our knowledge this was the first study to investigate the effects of a QMT program on flexibility, functional movement, dynamic balance, and muscular strength and endurance. Significant group × time interactions with medium to large effect sizes were found for 7 of the 18 range of motion measures, FMS CS and FMS sub-category CSs for the advanced movement patterns and the fundamental stability patterns. These findings support our initial hypothesis that the quadrupedal training program would result in significantly greater improvements over time in FMS scores and flexibility. Significant main effects for time, indicating improvements from pretest to post-test were observed for all YBT CSs, YBT UQ right and left medial reaches and left superolateral reach, YBT LQ right and left posteromedial and posterolateral reaches, right hip extension, left and right hip medial rotation, left and right ankle dorsiflexion, right shoulder lateral rotation, and push-up endurance regardless of group. These findings also support our hypothesis that significant improvements would be noted pretest to post-test, but fail to support the hypothesis that these improvements would be significantly greater than those of the control group.

Our primary finding is that while both groups improved upper body muscular endurance and dynamic balance, the QMT group showed significantly greater improvements to FMS scores and active joint range of motion compared with the CON group. Although the full utility of the FMS remains unknown, it is a simple means to identify potential erroneous habitual movement behaviors associated with certain movement patterns, which may lead to future injury (5,6). The relationship between composite FMS scores and injury risk remains questionable (3), with some research supporting no association (11,12,45) and others supporting some predictive power of a "cut-off" CS alone or in combination with additional factors (e.g., previous injury history, aerobic fitness, etc.) (14,22,24,31,37) Although questionable, a "cut-off" score of less than or equal to 14 seems to be the "gold-standard" used in clinical and research applications. Consistent with previous studies, in the present study, both groups' average CSs at baseline were below 14 (1,2,10,13,23,43). After the intervention, the GBMT group improved to 15.38 ± 1.91 (6% increase). The average change in the GBMT group from pretest to post-test was 1.62 points, which exceeds the minimally clinically important difference of 1.25 points previously established (4). In addition, before the intervention, 16 subjects in the GBMT group had CSs of 14 or less. Following the GBMT intervention only 6 subjects displayed CSs of 14 or less, an overall 62.5% reduction.

The improvements in FMS CSs seen in our study are consistent with existing literature showing average improvements ranging from 1.57 to 3.00 (2,3,24,40). These prior studies used corrective exercise interventions that used strategies from the FMS system to specifically improve mobility and stability requirements for each the FMS tasks. The exact mechanism for improvements observed in our study is unclear. The AF movements used in our study challenged similar joint ranges of motion and stability requirements seen in the FMS tasks. As an example, the *Loaded Beast* movement places subjects in a prone version of a deep squat. Keeping the knees elevated off the ground in this position requires significant whole-body stabilization and mobility. The QMT group showed a 17.5% improvement in the CSs for the fundamental stability subcategory indicating an improvement in whole-body stabilization strategies. These results provide an additional possible explanation for the overall improvements in FMS CSs and the advanced movement patterns subcategory CSs (16).

A second main finding from this study was that the QMT group experienced significantly greater improvements than the CON group in hip flexion, hip lateral rotation, and shoulder extension. These results are not all that surprising as many of the QMT intervention exercises were performed with the hips and shoulders at or near end ROM. These movements provided a combined passive and active stretching stimulus, both of which have been shown to improve active joint ROM (17,34,35,42). Each of the joint ROMs measured in our study were specifically challenged either actively or passively by at least one or several of the QMT movements practiced throughout the eight-week intervention period. In addition, hip flexion, hip lateral rotation, and shoulder extension were the joint ROMs challenged both actively and passively in nearly every AF level 1 movement, while most other joint ROMs were only challenged passively. For example, in the *Loaded Beast* position, the hips are passively taken into flexion (stretching posterior hips), whereas the hip lateral rotators are actively strengthened. In the *Beast Reach* exercise, the posterior hip is actively stretched by actively moving the upper leg into hip flexion.

As noted earlier, main effects for time were observed for several variables indicating improvements from pretest to post-test. These included all YBT outcomes (with the exception of YBT LQ right posterolateral reach score), right hip extension, right and left hip rotation, right and left ankle dorsiflexion, right should lateral rotation, and pushup test scores. Although pre-intervention to postintervention improvements were not significantly different between groups, these findings support our hypothesis that QMT can improve multiple fitness characteristics; however, there is not enough evidence to suggest that QMT is superior to general training for dynamic balance and upper body endurance. Handgrip strength remained unchanged pretest to post-test for both groups. Overall, these findings were surprising for several reasons. First, the QMT program imposed primarily closed kinetic chain demands on the upper extremities and core, which we hypothesized would lead to significantly greater improvements in YBT (especially UQ) and push-up scores for the QMT group. However, most of the movements practiced in the QMT program required the supporting upper extremities to remain close to the body. This contrasts with the demands of the YBT UQ which requires the reaching arm to extend as far as possible from the body and support arm. It is possible that more advanced QMT (i.e., Animal Flow Level 2) movements using extremity reaches further from the base of support would result in significant group differences. Second, the upper extremity focus of the QMT was thought to improve overall upper body muscular endurance. However, being a common exercise for recreationally active individuals, it is possible that push-ups were performed regularly during the invention period by both groups and contributed to the nonsignificant between group findings. In addition, most of the QMT was performed with a straight elbow position. Again, more advanced movements involve greater elbow flexion and may have resulted in significant differences between groups. Finally, HGS has been shown to improve following similar training styles (26,32); however, in these studies longer durations and different coaching for the hands were used then in the present study.

Several limitations to the study design must be considered when interpreting our findings. There were no significant differences between groups at baseline for any of the tests; however, we did not assess baseline cardiorespiratory fitness levels of subjects using standardized methods such as $\dot{V}O_2max$ testing and maximal strength testing. In addition, although there were no statistically significant differences between groups with respect to the amount of physical activity performed, the QMT group was clearly exposed to a greater amount of physical training with the addition of the 2 60 minute QMT sessions per week. It must also be noted that the exact amount of aerobic, resistance, and flexibility training was not taken into consideration for analysis. Some subjects may have performed more or less of a certain type of training (aerobic, resistance, or flexibility) as part of their normal routine than others. Given these limitations and our findings, future research addressing differences between just QMT and other types of training (yoga, Pilates, free weight training, etc.) is recommended. In addition, future research investigating acute and chronic effects of QMT on cardiorespiratory fitness would be useful for strength and condition professionals.

Practical Applications

Quadrupedal movement training is a form of bodyweight training gaining popularity in fitness, strength and conditioning, and physical rehabilitation settings. The present study used the Animal Flow level 1 programming for the QMT intervention; however, QMT encompasses a broad spectrum of programming. Our results indicate QMT can improve FMS scores and range of motion at the hips and shoulders. The results of this study provide consumers and health and fitness professionals with a better understanding of the benefits of QMT. As a form of bodyweight training, QMT is very accessible and can be used with a broad range of individuals and abilities. Based on our findings, QMT would be a plausible alternative training strategy used in warm-ups, embedded within a training program as accessory exercises or as a standalone training session for the purpose of improving joint range of motion and whole body stabilization concurrently.

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