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A Fully Virtual Graded Exertion Test is Safe and Feasible in Symptomatic and Asymptomatic Children with Concussion

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ABSTRACT

Context: Current graded exertion tests (GXT) for concussion management require specialized equipment and in-person supervision. The Montreal Virtual Exertion (MOVE) protocol is a telehealth compatible GXT but has only been tested in pseudo-virtual conditions.

Objective: To determine the safety and feasibility of the MOVE protocol when administered remotely to children with concussion. **Design**: Prospective cohort study.

Setting: Participants were recruited from the [redacted] between November 2023 and June 2024. Patients: Asymptomatic (n=15, 40.8±19.2 days after concussion) and symptomatic (n=15, 28.7±23 days after concussion) children with concussion (aged 12.9 ± 2.6 years, $n_{females}$=18).

Main Outcome Measures: Participants completed the MOVE protocol and a 24hr follow-up visit over Zoom. The MOVE protocol consists of seven plyometric exercises performed for 60sec, with 60secs of rest between stages. Safety (adverse events) and feasibility measures (protocol, outcomes, intensity, and technology categories) were collected. Linear mixed models evaluated exercise intensity outcomes, with all other outcomes analyzed using chi-square tests.

Results: Participants in the symptomatic (n=1) and asymptomatic (n=1) groups experienced a minor adverse event (symptom increase ≥10 points on the PCSI at 24h visit); however, no major adverse events were reported. Heart rate (ΔHR= 78.7± 33.6,

p<0.001) and rate of perceived exertion (ΔRPE= 4.87±1.50, p<0.001) change scores significantly increased throughout the MOVE protocol, but no main effect of group or interaction effects were observed. Feasibility outcomes were less likely to be captured during the rest period for asymptomatic children (outcomes not collected on time on 33 (31.4%) occasions) than symptomatic children (11 (11.7%) occasions; $\chi^2(1)=10.1$, p< 0.001). Otherwise, all outcomes met the a priori definition of feasibility.

Conclusion: The MOVE protocol can be safely and feasibly administered virtually. A no-equipment, virtual GXT can remove barriers to exercise testing and broaden access to best practice concussion management strategies.

Abstract Word Count: ***296*** words

KEY WORDS: *mild traumatic brain injury, pediatrics, exercise, telehealth, telemedicine*

KEY POINTS

1. The MOVE protocol is a safe and feasible GXT when administered virtually to symptomatic and asymptomatic children with concussion.
2. The MOVE protocol removes common barriers to validated GXTs for concussion management, increasing its potential to expand best practice management strategies to children with concussion.

Introduction

Concussion is a common injury among Canadian children, accounting for one in 70 visits to pediatric emergency rooms.[1] Current best practice guidelines for concussion management recommend 24-48 hours of rest,[2,3] after which sub-symptom threshold aerobic exercise is suggested to reduce symptoms and expedite recovery.[3] While various methods for aerobic exercise prescription are available following concussion, including the use of age-predicted heart rate estimates, an individualized approach to exercise prescription is ideal.[4] Graded exertion tests (GXTs) can determine the unique sub-symptom heart rate threshold required for precise and tailored post-concussion exercise prescriptions,[5] which promote faster recovery from concussion.[6,7] GXTs can also be used acutely to identify children at risk of prolonged recovery[8] or at the end of the recovery period to support return-to-play decision-making.[9] As such, GXTs have become an increasingly important tool for concussion management.

GXTs developed for concussion patients are safe and feasible for children.[7,10] While no-equipment GXTs are used in other populations, current GXTs validated for clinical concussion care are incompatible with virtual administration due to required in-person supervision and specialized equipment. Telehealth administration of post-concussion exercise programming may come with drawbacks, including challenges with adherence[11,12] and motivation.[13] However, telehealth services improve patient care by reducing burdens to in-person care, increasing access to healthcare providers, and enhancing communication across multidisciplinary teams.[14] Furthermore, children with concussion living in rural locations experience greater costs associated with post-injury rehabilitation despite the underutilization of these services.[2] Thus, GXTs that can be

performed at home under virtual supervision could reduce barriers to care for patients living in underserved areas, diminish transportation **and** financial costs, **and** improve access to care for individuals with symptoms or pre-existing conditions **that** make in-office visits challenging.[15]

A virtual GXT could expand exercise testing in concussion management practices, both for prescribing aerobic exercise to symptomatic patients and supporting the multimodal framework for medically clearing asymptomatic children to return to sport. The Montreal Virtual Exertion (MOVE) protocol was designed as an equipment free, telehealth compatible protocol for concussion patients to address challenges with current GXTs. The MOVE protocol was tested in a partially virtual setting in children with concussion,[16] but it's safety and feasibility when administered in a fully virtual setting remains unknown. Therefore, our objective is to determine if the MOVE protocol is safe and feasible when delivered remotely to asymptomatic and symptomatic children with concussion. Our central hypothesis is that the MOVE protocol will be a safe and feasible virtual exercise test in children with concussion.

METHODS

Participants

A convenience sample of children with concussion were recruited from the [redacted] between November 2023 and June 2024. Inclusion criteria were being 1) aged 5-17 years, 2) fluent in English or French, 3) of sufficient cardiovascular health to exercise (i.e., answering "no" to all seven questions on the Physical Activity Readiness Questionnaire for Everyone), 4) diagnosed with a concussion by a licensed healthcare professional, 5) available for testing within 7 days

of study enrollment, 6) able to access a device with internet, microphone, and webcam, and 7) having a parent or legal guardian available during the virtual test session. Children were excluded if they 1) had any current injury or illness that would prevent them from exercising, 2) had any history of moderate or severe brain injury, or another concussion within the past 12 months, or 3) were highly symptomatic (≥7 out of 10 on the global symptom scale) at the time of testing. Written parental consent and youth assent were obtained, and participants rights and confidentiality were protected in line with local and federal guidelines. This study was approved by the [redacted]

Procedures

Each child completed two virtual study visits in either French or English based on participant preference. Both visits were conducted within their own home over a secure, institutional Zoom Enterprise account. Demographic, self-reported general fitness, and post-concussion symptom outcomes were captured at the initial visit. Then, a short orientation session provided instructions on recording manual pulse, reviewed all study outcomes, and described and demonstrated each MOVE protocol exercise. Each child was asked to model the MOVE protocol exercises and, if needed, corrections were provided until each movement was performed correctly. After the orientation, the MOVE protocol was performed. The MOVE protocol includes seven plyometric exercises performed for 60 seconds each, followed by a 60 second rest period to capture study outcomes. The seven exercises (in order of completion) are walking in place, slow jog, moderate jog, and fast jog in place, jumping jacks, high knees, and quick steps (SUPPLEMENTARY FIGURE 1). Participants were instructed to sustain the highest

intensity they could consistently maintain for the full stage. Each exercise requires increasingly higher metabolic equivalents (according to the Compendium of Physical Activities), mimicking the progressive nature of traditional GXTs.[17] All MOVE protocol stages were performed unless one of the following occurred: 1) an adverse event, 2) an increase of ≥3 points from baseline on the 0-10 global symptom scale, 3) the participant asked to stop, or 4) any concerning sign or symptom was observed by the test evaluator. The test evaluators, who were two undergraduate students in the final year of their exercise science degree, monitored the participant throughout the protocol with a parent/legal guardian also present inside the home during testing. A 5-minute follow-up visit was virtually conducted 24hrs later to assess for any delayed safety concerns (i.e., late onset symptom exacerbation).

Outcome Measures

Safety: Safety was defined a priori as less than or equal to three minor and/or two major adverse events based on prior literature.[18] Minor adverse events included 1) a fall, 2) a musculoskeletal injury not requiring any medical attention, or 3) a meaningful increase in concussion symptoms at the 24hr follow-up (≥10-point change from pre-exercise values on the Post-Concussion Symptom Inventory). Major adverse events included 1) a new injury (concussion, musculoskeletal, etc.) requiring medical attention or 2) any post-protocol symptom exacerbation requiring medical attention. Early termination of the MOVE protocol due to symptom exacerbation was not considered an adverse event because exercise tolerance is a known condition following concussion.[8]

Feasibility: Protocol feasibility was evaluated based on the ability to 1) complete the assessment virtually, 2) perform the protocol as designed, 3) collect study outcomes during the 60-second rest period, and 4) establish the progressive intensity of the protocol. Feasibility was defined as ≥ 80% of the outcomes being successfully completed in at least three categories.

Post-Concussion Symptom Inventory (PCSI): The PCSI is a developmentally tailored concussion symptom checklist for children. The 13-18-year-old PCSI version was used, which lists 20 items on a 7-point scale from 0 (not present) to 6 (present and severe). The PCSI was completed before and 24 hours after the MOVE protocol administration. The outcome of interest was the total symptom score (0 to 120), with higher scores indicating more frequent and severe symptoms. The PCSI is a reliable[19] and valid[20] questionnaire used extensively in the pediatric concussion literature.

Heart Rate: Pulse was manually taken at either the carotid or radial artery (participant preference) as a proxy for heart rate by the participant (n=16) or, if the child had difficulty taking the measurement, their parent (n=14). Pulse was taken for 15 seconds and multiplied by 4 to result in beats per minutes. Pulse was measured before the MOVE protocol and during the rest period between each stage. Manual pulse has been used in post-concussion GXTs to monitor exercise intensity.[21]

BorgCR10 Scale (Child-Friendly Version): The BorgCR10 scale captured rate of perceived exertion (RPE) from 0 (asleep) to 10 (maximum exercise) on a colorful, numeric scale including pictorial facial expressions to mimic effort level.[22,23] RPE was assessed at rest before the test and between each MOVE protocol stage to capture a

subjective measure of protocol difficulty. The BorgCR10[24] scale is commonly used to evaluate effort during post-concussion GXTs.[21]

Global Symptom Scale: The global symptom scale assessed overall concussion symptoms from 0 (terrific, no symptoms) to 10 (terrible, worst I ever felt) on a visual analogue scale. The global symptom scale was administered at rest prior to protocol initiation and following each MOVE protocol stage. The global symptom scale is commonly used to assess global symptom presentation during GXTs in concussion patients.[15,19] This outcome was a stopping criterion (≥3pt increase) for patient safety.

Activity Limiting Symptoms: Participants completed a single-item measure capturing the extent to which current symptoms impact the ability to engage in everyday activities. This scale ranges from 0 (no activities are limited) to 3 (most activities are limited) and evaluates a more functional aspect of symptom reporting. This item was assessed before and 24hrs after the MOVE protocol.

Child and Parent Satisfaction: Children and their parent rated their satisfaction from 0 (not satisfied at all) to 10 (extremely satisfied) to capture their overall experience with the MOVE protocol.

Statistical Analysis

Statistical analyses were performed in RStudio (Version 4.0.0, 2020-04-24). Descriptive statistics are presented as frequencies and percentages (categorical) or means and standard deviations (continuous). For heart rate, RPE, and global symptom outcomes obtained throughout the MOVE protocol, linear mixed models assessed main effects of group (asymptomatic vs. symptomatic patients), MOVE protocol stage, and their interaction. Linear mixed models also assessed main effects of group, time (initial

visit vs. 24hr follow-up), and their interaction on PCSI and symptom limited activities outcomes. A repeated term accounted for multiple observations from the same participant and, when significant, post hoc testing (Tukey's test) evaluated each pair-wise comparison. Chi-square or Fisher's exact tests compared binary feasibility outcomes between groups. Adjusted p-values are presented throughout where appropriate, and significance was set to $p<0.05$.

RESULTS

Thirty-one children enrolled in the study; however, one child was unable to participate due to time constraints, resulting in a final sample of 30 participants. Children were assessed approximately 5-week post-injury (symptomatic: 28.7±23 days, asymptomatic: 40.8±19.2 days). Compared with symptomatic children (n=15), asymptomatic participants (n=15) were less likely to speak English as their primary language (p=0.03) and self-reported higher general fitness levels (p=0.03). Otherwise, no significant differences in patient characteristics were observed between groups (TABLE 1).

The MOVE Protocol is Safe for Symptomatic and Asymptomatic Children with Concussion

Four (26.7%) MOVE protocol administrations were ended early for symptomatic children due to acute post-protocol symptom increases, while all (n=15, 100%) asymptomatic participants completed the full protocol (p= 0.10). One symptomatic patient who terminated the MOVE protocol early due to acute symptom exacerbation and one asymptomatic patient who completed the full MOVE protocol without issue

went on to experience a ≥10-point increase in post-protocol symptoms at the 24hr follow-up, for a total of two minor adverse events reported (one per group, p=1). No major adverse events were reported in conjunction with the MOVE protocol. Symptomatic patients (Initial: 15.1 ± 12.3, Follow-Up: 14.1 ± 14.5) generally reported higher scores on the PCSI than asymptomatic individuals (Initial: 4.07 ± 5.75, Follow-Up: 2.13 ± 6.64, $t_{(38.4)}$=2.89, p=0.006). However, no effect of visit or interaction was observed (p>0.38). Therefore, although two individual patients had increased post-protocol symptoms at the 24hr follow-up, scores were very stable between visits for both groups (FIGURE 1). Similar results were obtained for symptom limited activities; symptomatic patients (Initial: 1.60 ± 1.06, Follow-Up: 1.47 ± 1.13) reported greater difficulties with activities of daily living than asymptomatic patients (Initial: 0.20 ± 0.56, Follow-Up: 0.13 ± 0.52, $t_{(31.3)}$=4.46, p<0.001), but no effect of visit or interaction effect was observed (p>0.53).

The MOVE Protocol is Feasible in Symptomatic and Asymptomatic Children with Concussion

Two outcome measures had suboptimal feasibility. Outcomes were successfully captured within the 60sec rest period on only 76 (68.8%) and 83 (88.3%) occasions for asymptomatic and symptomatic patients, respectively ($\chi^2_{(1)}$=10.1, p=0.001). Reasons for the delayed capturing of outcomes include indecisiveness in reporting RPE or symptom scores (n=25), challenges in taking pulse manually (n=11), taking short breaks to drink water or adjust shoes (n=8), and a virtual connectivity issue (n=1). The MOVE protocol was administered in 15.9±1.6 minutes in the asymptomatic group versus 13.8±3.6 minutes in the symptomatic group ($t_{(19.5)}$=2.10, p=0.049). However, due to the delayed

capturing of outcomes during the 60sec rest period described above, less than 80% of all MOVE protocol administrations (19/30, 63.3%) were completed in less than 15 minutes. All other feasibility outcomes were completed with high success rates and the MOVE protocol met the a priori definition of feasibility (TABLE 2).

Heart rate (ΔHR= 78.7$\pm$ 33.6 ($F_{(7, 185.5)}$=83.3, p<0.001) and RPE (ΔRPE= 4.87$\pm$1.50, $F_{(7, 185.2)}$=128.8, p<0.001, FIGURE 2) change scores significantly increased throughout the MOVE protocol, but no group or interaction effects were observed (p>0.13). Main effects of group ($F_{(1, 27.8)}$=16.6, p<0.001) and time (Δsymptom= 1.23$\pm$ 1.33 $F_{(7, 184.0)}$=9.45, p<0.001) were found for global symptom change scores, with the symptomatic group reporting higher symptoms overall and symptoms generally increasing throughout the MOVE protocol (TABLE 3). Children (9.2 ± 1.2, $t_{(23.07)}$=-0.3, p=0.76) and their parents (9.63 ± 0.68, $t_{(10.8)}$=-0.27, p=0.79) reported high rates of overall satisfaction with the MOVE protocol, which were similar between symptomatic and asymptomatic children with concussion.

DISCUSSION

The MOVE Protocol is safe and feasible when administered virtually to symptomatic and asymptomatic children with concussion in the subacute or chronic phases of recovery. Four symptomatic patients terminated the MOVE protocol early due to symptom exacerbation. Exercise intolerance following a concussion is expected[8] and, therefore, these early protocol terminations were not considered adverse events. Conversely, one symptomatic and one asymptomatic patient experienced a sustained increased of ≥10pts on the PCSI at the 24hr follow-up (e.g., minor adverse events). The symptomatic patient experienced a major life stressor (confirmed by the parent) in

between study visits, while the asymptomatic patient passed a standard, in-person GXT as part of their clinical recovery assessment with no symptoms exacerbation within the 24 hours following the GXT. Furthermore, concussion symptoms are non-specific and external stressors[25], pre-existing mental health conditions[26], and other factors[27] can provoke higher symptom reporting. Thus, the two minor adverse events may not be directly related to the MOVE protocol itself. Regardless, adverse events remain low and average symptoms scores were stable between visits, similar to a partially virtual administration of the MOVE protocol.[16] Exercise interventions in individuals with concussion also report similarly few significant symptom exacerbations and safety concerns.[10,18,28] Ultimately, the safety of the MOVE protocol is high and comparable to other studies implementing aerobic exercise protocols in patients with concussion.

Heart rate and perceived exertion increased throughout the MOVE protocol, confirming the progressive intensity of the protocol. Heart rate and RPE at MOVE protocol termination (i.e., maximum heart rate and RPE values) are comparable to established GXTs,[7,10] suggesting a similar overall intensity to in-person testing. Most feasibility outcomes were completed with high success rates, except for collecting all outcome measures within the 60 second rest periods and, consequently, completing the entire protocol within the 15-minute time window. Cordingley et al. evaluated the feasibility of the Buffalo Concussion Treadmill Test in pediatric concussion patients and found that the duration ranged from 4-34 minutes (mean=18).[29] This average is similar to the mean MOVE protocol duration, although the MOVE protocol has a predetermined stopping point and, thus, less variability in total test time. Our feasibility results are also

comparable to a partially virtual administration of the MOVE protocol,[16] with the current study finding that its established feasibility extends to fully virtual conditions.

Strengths

GXTs currently used to manage concussion require in-person supervision and specialized equipment. The bodyweight exercises and use of Zoom allow the MOVE protocol to be performed within the comfort of the participants' and evaluators' homes. Thus, a major strength and novelty of the MOVE protocol is that it can be administered in a completely virtual environment. Post-concussion exercise programs often use repetitive, structured physical activity (e.g., running, cycling, etc. for 20-30 minutes); in addition to the required equipment, these programs are not always developmentally appropriate for the physical and cognitive needs of younger children. Plyometric exercises, such as those used in neuromuscular training programs, are feasible following return to play clearance from concussion[31] and can reduce sport-related injuries following return-to-play.[32] The plyometric exercises used in the MOVE protocol were carefully selected to ensure they are simple and easily understandable for young children. This ensures each exercise is performed properly on almost every occasion and makes the protocol accessible to younger participants, further extending the use of plyometric exercises for concussion management. GXTs have multiple uses in clinical concussion management, such as prescribing individualized exercise programs and determining readiness to return to sport.[33] Thus, our inclusion of both symptomatic and asymptomatic children establishes the safety and feasibility of the MOVE protocol in relation to multiple, clinically relevant scenarios. Virtual administration fosters

accessibility, enhances patient compliance, and facilitates early intervention,[34] which may ultimately improve recovery and support safe return to activity.

Limitations

Both symptomatic and asymptomatic children in our study were evaluated several weeks post-concussion. This may have influenced symptomatic children's response to the MOVE protocol as exercise intolerance typically improves throughout recovery.[33] The safety and feasibility of the MOVE protocol in acutely injured patients must be evaluated in future studies given the various pathophysiological deficits present within the first days to weeks after concussion. Several participants had difficulty taking their pulse manually, which resulted in outcomes being collected outside the 60sec rest period. Future studies should consider the use of a heart monitor or fitness tracker in place of manual pulse when feasible. Mechanism of injury was not captured. As symptom severity[35] and exercise intolerance[36] can be influenced by the mechanism of injury, this should be considered in the future. All questionnaires were provided in both English and French due to the high proportion of anglophone and francophone speakers in our local community. Only the BorgCR10 is formally validated in French;[37] all other assessments were translated by a bilingual researcher with native proficiency in both French and English. The clinical site from which we recruited typically manages complex cases often resulting in delayed recovery. Thus, our participants may not be generalizable to typically recovery pediatric concussion patients. Finally, future studies should evaluate the safety and feasibility of the MOVE protocol in adults, which may differ from pediatric populations.

Clinical Implication

As GXTs are a key tool in concussion management,[8] a safe, feasible, and telehealth-compatible protocol could remove barriers associated with current use and expand options for virtual care in the future. Athletic therapists have limited time allowed with their patients. The consistent duration of the MOVE protocol may help athletic therapists better manage appointments, allocate resources, and optimize workflow. Athletic therapists employed in high school or collegiate settings often manage multiple sports teams simultaneously,[38] routinely travelling with one team while continuing to manage patients from other teams remotely. The MOVE protocol provides an equipment-free GXT alternative for athletic therapists if equipment is unable or the athlete and athletic therapist are physically separated due to travel. Thus, the MOVE protocol may reach a wider range of youth athletes and increasing the implementation of a critical concussion management tool for athletic therapist. Future studies should investigate the potential of the MOVE protocol to guide individualized exercise prescription (i.e., identify a heart rate threshold at which symptoms increase to prescribe a target intensity at 80-90% of that threshold), which could further extend its clinical utility in clinical concussion management.

Conclusion

The MOVE protocol is a safe and feasible GXT for both symptomatic and asymptomatic children in the subacute and chronic phases of concussion recovery when administered virtually. There were no major adverse events, feasibility standards were achieved, and participants and their parents expressed high levels of satisfaction with the MOVE protocol. Heart rate and RPE increased significantly throughout the

protocol, confirming the progressive intensity as intended. Future studies should investigate the MOVE protocol in other relevant clinical scenarios, such as for guiding post-concussion exercise prescriptions and acutely after injury.

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FIGURES LEGENDS

FIGURE 1. Change in PCSI total score for asymptomatic (A) and symptomatic (B) patients across study visits. Black lines represent individual subject change, while the red line reflects the group average.

FIGURE 2. Line graphs depicting average heart rate (A), RPE (B), and global symptom scale ratings (C) throughout the MOVE protocol for asymptomatic and symptomatic children.

Note: BPM= beats per minute, RPE= rate of perceived exertion. MOVE protocol stages: Rest, Walking in Place (Walk), Slow Jog in Place (SJog), Moderate Jog in Place (MJog), Fast Jog in Place (FJog), Jumping Jacks (JJacks), High Knees (HKnees), & Quick Steps (QSteps).

SUPPLEMENTARY FIGURE 1. Information sheet given to all participants, providing an overview of the MOVE protocol procedures and written instructions for completing each exercise.

Tables and Figures

TABLE 1. Descriptive statistics for participant characteristics by group. Continuous outcomes are presented as mean (SD), while categorical variables are presented as n (%).

	Asymptomatic (N=15)	**Symptomatic** (N=15)	**Overall** (N=30)	***P* Value**
Age (Years)	12.9 (2.71)	12.9 (2.46)	12.9 (2.55)	1
Sex				
Female	9 (60.0%)	9 (60.0%)	18 (60.0%)	1
Male	6 (40.0%)	6 (40.0%)	12 (40.0%)	
Primary Language				
English	4 (26.7%)	11 (73.3%)	15 (50.0%)	0.03
French	10 (66.7%)	4 (26.7%)	14 (46.7%)	
Spanish	1 (6.7%)	0 (0%)	1 (3.3%)	
Concussion History				
1+ Prior Concussion	3 (20.0%)	2 (13.3%)	5 (16.7%)	1
No Prior Concussion	12 (80.0%)	13 (86.7%)	25 (83.3%)	
Presence of Pre-Existing Conditions				
1+ Pre-Existing Condition	5 (33.3%)	5 (33.3%)	10 (33.3%)	1
No Pre-Existing Condition	10 (66.7%)	10 (66.7%)	20 (66.7%)	
General Fitness Relative to Peers				
Much less fit	0 (0%)	0 (0%)	0 (0%)	0.03
Somewhat less fit	0 (0%)	2 (13.3%)	2 (6.7%)	
Equally as fit	5 (33.3%)	9 (60.0%)	14 (46.7%)	
Somewhat more fit	8 (53.3%)	1 (6.7%)	9 (30.0%)	
Much more fit	2 (13.3%)	3 (20.0%)	5 (16.7%)	
Pre-Injury Physical Activity				
Minutes per week	428 (263)	335 (194)	382 (232)	0.28
Days per week	2.67 (1.95)	1.87 (1.41)	2.27 (1.72)	0.21
Days Since Concussion	40.8 (19.2)	28.7 (23.0)	34.7 (21.7)	0.13

Note: Pre-injury physical activity outcomes, including minutes per week and days per week, were self-reported by the participant.

TABLE 2. Feasibility outcomes for both asymptomatic and symptomatic participants. All four categories met the a priori definition of feasibility.

Category	Feasibility Definition	Outcomes Evaluated	Observed Success Rate		Is MOVE Feasible?
			Asymptomatic	*Symptomatic*	
Exertion Protocol	Average success rate ≥80%	1. No contraindications to exercise 2. Space to perform exercises 3. Movement performed correctly* 4. Movement performed for 60s* 5. Test performed ≤15 mins	1. 15 (100) 2. 15 (100) 3. 104 (99.0) 4. 105 (100) 5. 7 (46.7)	1. 15 (100) 2. 15 (100) 3. 94 (100) 4. 94 (100) 5. 12 (80.0)	Yes
Outcomes Measures	Average success rate ≥80%	1. Pulse collected appropriately 2. Outcomes collected during rest* 3. Outcomes collected at follow-up	1. 15 (100) 2. 72 (68.6) 3. 15 (100)	1. 14 (93.3) 2. 83 (88.3) 3. 15 (100)	Yes
Progressive Intensity	Increases throughout protocol	1. Heart rate 2. RPE	1. $F_{(7, 185.5)}$=83.3, p<0.001 2. $F_{(7, 185.2)}$=128.8, p<0.001		Yes
Technology	≥80% success rate	1. Virtual sessions completed without technology issues	1. 15 (100)	1. 14 (93.3)	Yes

Note: The outcomes labeled with an asterisk were collected for each MOVE protocol stage. These outcomes were collected on 105 occasions for asymptomatic patients (15 participants x 7 MOVE protocol stages). As some symptomatic patients terminated the MOVE protocol early due to symptom exacerbation, these outcomes were collected on 94 occasions for patients with on-going symptoms. All other categorical outcomes were collected once per session (n = 15 for each group).

TABLE 3. Manual heart rate values, rate of perceived exertion, and global symptoms scores by group throughout the MOVE protocol, presented as mean (SD).

	Rest	Walk	Slow Jog	Medium Jog	Fast Jog	Jumping Jacks	High Knees	Quick Steps	Overall
Heart Rate (bpm)									
Asymptomatic	72.0 (18.8)	79.4 (17.2)	92.0 (20.0)	107 (23.9)	120 (28.9)	134 (31.9)	144 (32.1)	155 (39.1)	113 (39.1)
Symptomatic	79.6 (14.5)	88.4 (15.4)	104 (26.0)	116 (27.1)	135 (29.2)	143 (33.9)	145 (32.4)	149 (29.2)	117 (35.8)
RPE									
Asymptomatic	1.07 (0.59)	1.67 (0.72)	2.13 (0.83)	2.87 (0.83)	3.53 (0.92)	4.27 (1.22)	5.27 (1.49)	5.53 (1.60)	3.29 (1.87)
Symptomatic	0.87 (0.52)	1.47 (0.74)	2.40 (0.91)	3.40 (1.18)	4.36 (1.28)	4.75 (1.42)	5.50 (1.09)	5.55 (1.57)	3.37 (1.99)
Symptoms (0-10 scale)									
Asymptomatic	0.07 (0.3)	0.13 (0.35)	0.20 (0.78)	0.40 (0.83)	0.47 (0.83)	0.53 (0.99)	0.67 (0.98)	0.67 (1.2)	0.39 (0.83)
Symptomatic	1.60 (0.99)	1.53 (1.13)	1.73 (1.44)	2.47 (1.96)	2.36 (1.91)	2.25 (1.76)	2.33 (2.06)	2.09 (1.97)	2.03 (1.65)

Note: bpm (beats per minute), RPE (rate of perceived exertion)

FIGURE 1. Change in PCSI total score for asymptomatic (A) and symptomatic (B) patients across study visits. Black lines represent individual subject change, while the red line reflects the group average.

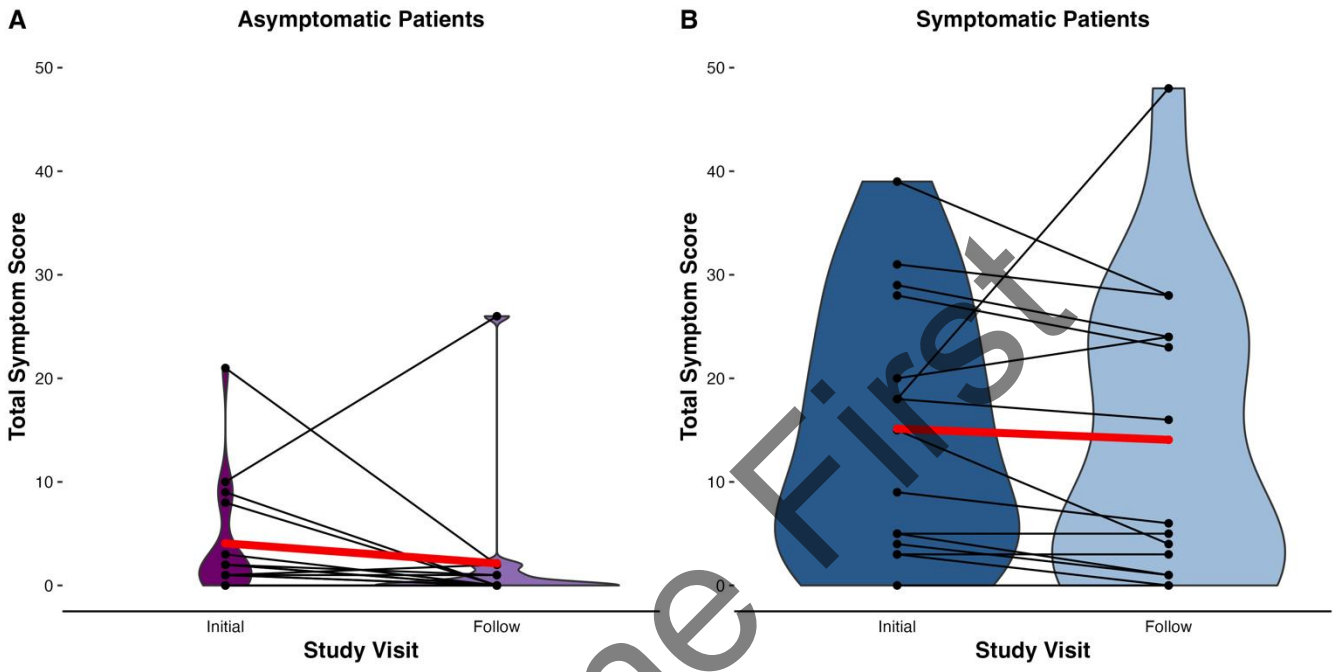
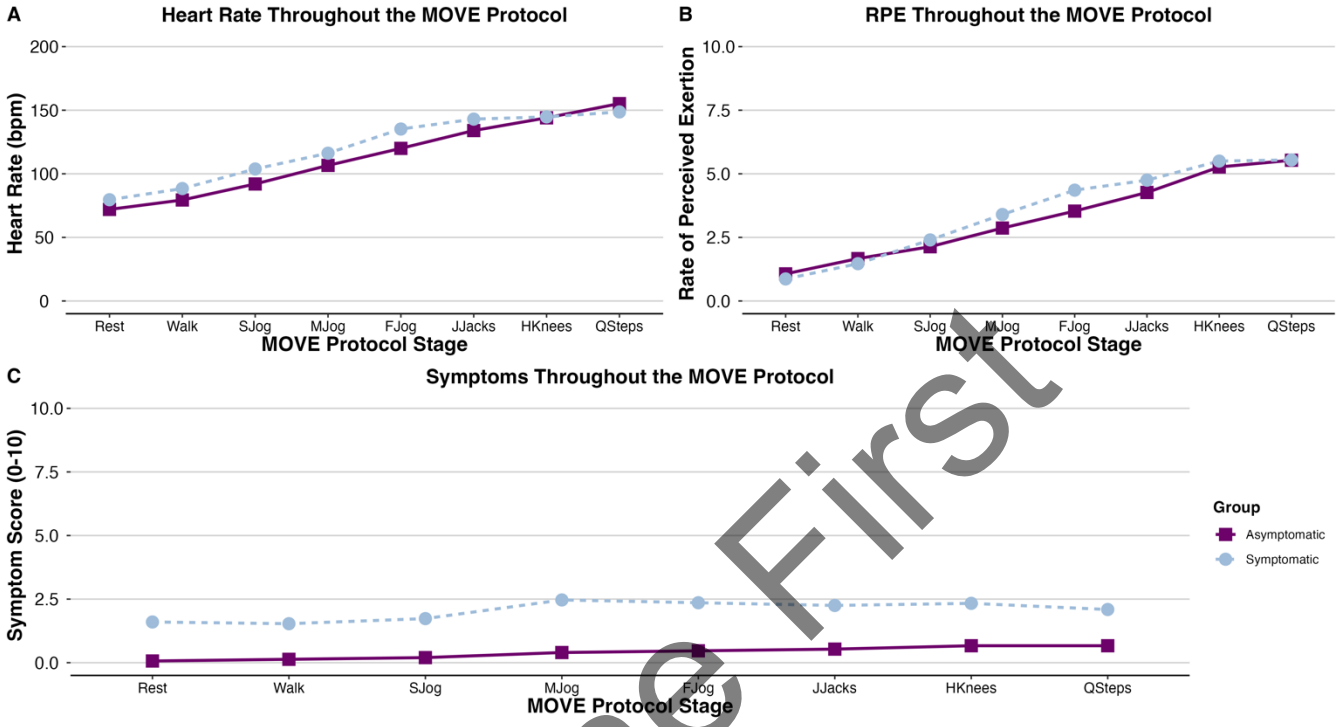


FIGURE 2. Line graphs depicting average heart rate (A), RPE (B), and Global Symptom Scale ratings (C) throughout the MOVE protocol for asymptomatic and symptomatic children.



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