Frame Running as a community-based exercise option for young people with moderate-to-severe walking impairments: a feasibility study.

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Abstract

Frame Running is an adapted community-based exercise option for people with moderate-to-severe walking impairments. This mixed-methods study aimed to examine the feasibility of 1) community-based Frame Running by young people with moderate-to-severe walking impairments and 2) conducting future studies on the impact of Frame Running on functional mobility and cardiometabolic disease risk factors. Weekly training sessions and data collection occurred in two sites. Quantitative data were collected at baseline, and after 12 (both sites) and 24 (one site) weeks of training, followed by interviews or focus groups. Consent and retention rates, attendance and outcome measure completion rates were calculated. Qualitative data were analysed abductively using concurrent inductive and deductive thematic content analysis. Data for the assessments at baseline, 12 and 24 weeks were available for 23, 15 and 5 participants respectively. Participants were aged 5-25 with most diagnosed with cerebral palsy (GMFCS II-IV). Consent, intervention drop-out and adherence rates were 55%, 17% and 83% respectively with no serious adverse events. Outcome measure completion rates ranged between 60% and 98%. Themes related to facilitators to participating in Frame Running were mostly identified in the personal and social domains with barriers more common in the environmental and policy domains. The study results support the existing evidence that Frame Running is a safe and acceptable community-based exercise option for those with moderate-to-severe walking impairments. Themes identified in personal, social, environmental, and policy domains can guide the implementation of community-based Frame Running participation. Our feasibility data can inform the design of future definitive studies.

Keywords: Frame Running, disability sport, physical activity, exercise, cerebral palsy, feasibility, mixed-methods, qualitative

Introduction

Children and young people with moderate-to-severe walking impairments due to long-term physical health conditions such as cerebral palsy (CP) are often less physically active than their peers.[1] This is concerning as reduced participation in moderate-to-vigorous physical activity (MVPA) is a modifiable risk factor for non-communicable diseases and likely contributes to the heightened risk of cardiovascular disease observed in people with CP.[2] Despite growing evidence supporting the efficacy of exercise and physical activity interventions in enhancing aspects of physical fitness for independently ambulant people with CP,[3] research on aerobic activities tailored for those with moderate-to-severe mobility impairments remains relatively scarce.

Frame Running, formerly known as RaceRunning, has emerged as an adapted form of exercise that enables those with mobility impairments to safely engage in MVPA.[4,5] Utilising a three-wheeled frame with a saddle and chest plate for support, participants propel themselves forward using their feet and legs. Recent studies have found that Frame Running may offer a potential moderate to high-intensity training stimulus,[4] yielding favourable outcomes such as improved Frame Running endurance and muscle thickness of gastrocnemius[5] as well as enhanced psychosocial outcomes.[6] Further, a recent study by Sukal-Moulton et al.[7] explored the feasibility of a sport-based youth development running programme which consisted of a mix of on-line exercise sessions (during the COVID-19 pandemic) and weekly Frame Running sessions in a public park (16 weeks) and indoor Frame Running sessions taking part in schools (further 8 weeks). Our study, employing a robust mixed-methods approach, further adds to the evidence on the feasibility, safety and acceptability of weekly outdoor Frame Running training sessions that are already supported by local athletics clubs. Understanding the personal, environmental, social, and policy factors influencing participation in Frame Running may support sustained implementation, which is crucial for ensuring its positive impact on the health outcomes of children and young people. Thus, objectives of this mixed-methods study were :1) to examine the acceptability, safety and perceived barriers and facilitators associated with taking part Frame Running as a community-based exercise option for young people with moderate-to-severe walking impairments such as those with CP and 2) to assess the feasibility of conducting future studies on the impact of Frame Running on cardiometabolic disease risk factors and functional mobility in this population. Both aims were addressed through the collection of qualitative and quantitative data.

Materials and Methods

Study design

The current study had a mixed-method design influenced by a pragmatist paradigm. In pragmatism, methodological choices are influenced by a practical research philosophy. Pragmatism places value on "subjective" and "objective" knowledge and allows the researcher to adopt methods suitable for the research question.[8] A convergent parallel design was used where quantitative data collection and analysis did not influence the qualitative part or vice versa.

This study was a single arm, pre-post open label trial with Frame Running training sessions and data collection taking place in two geographical areas, central Scotland (site A) and Southwest England and Wales (site B). Assessments of quantitative outcomes were conducted at baseline, and after 12 (both sites) and 24 (site A only) weeks of weekly Frame Running sessions, followed by qualitative data collection through athlete interviews or focus groups.

Due to the COVID-19 pandemic, quantitative data collection involving in-person assessments was temporarily paused. Consequently, the original study protocol[9] was amended in two ways to enhance our data collection regarding our first aim. Firstly, we invited Frame Running athletes to take part in remote interviews irrespective of whether they had participated in the quantitative data collection. Secondly, we also invited other stakeholders, namely parents of athletes, coaches and others involved in promoting and implementing Frame Running to participate in the qualitative data collection.

The description of quantitative and qualitative aspects of this study adheres to the reporting standards outlined by the Consolidated Standards or Reporting Trials (CONSORT),[10] the Consolidated Criteria for Reporting Qualitative Research (COREQ)[11] and the Consensus on Exercise Reporting Template (CERT) (supplementary material 1).[12] Ethical approval was received from the National Health Service (NHS) Research Ethics Committee (reference:19-SS-0035) and the University Research Ethics Committee prior to the commencement of the study (trial number registration: NCT04034342). The amendments to the original protocol were approved by the same University Research Ethics Committee.

Quantitative data collection

Participants

Participants were recruited through email invitations circulated among local Frame Running clubs and schools for both site A (Edinburgh area and Fife) and site B (Gloucester, Bath and Cardiff) and through local paediatric physiotherapists (site A only). Participants were eligible if they were 5 to 25 years, diagnosed with CP or another physical disability causing mobility and balance impairments equivalent to a Gross Motor Function Classification System (GMFCS) level of II-IV, had ≤ 15 hours of Frame Running experience and able to independently propel the frame for at least 20 metres. Participants provided either informed written consent or assent (if aged 17 or younger), with parental consent obtained for those under 18 years.

Frame Running training sessions

Participants took part in weekly one-hour long Frame Running training group sessions for at least 12 weeks at their local community athletics club (5 clubs in total). Participants continued with their usual care throughout the Frame Running study period. The Frame Running training sessions were conducted outdoors on a 400m synthetic athletics track and were led by qualified athletics coaches (UK level I or II) who had attended a Frame Running coaching course organised by Frame Running Scotland or CP Sport. For all five clubs, the majority of the frames were purchased and owned by the athletics club and stored near the athletics track in either dedicated storage space or a sea container. Participants used a frame that was adjusted to their body dimensions and running style while optimising either comfort or speed or a balance of both. Transport to and from the track was provided by parents and other family, friends, carers or personal assistants. Prior to the study the overall aim and structure of the Frame Running sessions was discussed with the qualified athletics coaches who then designed their own programmes accordingly. Session content varied but included ladder drills (e.g., one foot hopping, bunny hops, fast feet) and intervals ranging from 10 to 200m (supplementary material 2). As local entry-level Frame Running competitions typically involve distances between 40 and 200m, the emphasis was primarily on sprint performance rather than endurance. Coaches ensured that sessions included age-appropriate fun elements and games to optimise engagement. The volume and intensity of each session was adjusted according to the athletes' abilities and increased accordingly over the training period.

Fidelity

Fidelity was assessed by recording attendance at Frame Running sessions and monitoring heart rate (HR) during two training sessions using a photoplethysmography-based HR sensor (Polar M200, Polar, Finland) to elucidate exercise intensity. We calculated the average HR during the training session as a percentage of maximum HR (HR_{max}), using the value of HR_{max} of 194 beats/min for participants under 18 years.[13]

Brief description of the outcome measures

Please see our published protocol for a detailed description of the outcome measures collected before and after 12 (both sites) and 24 weeks (site A only) of weekly Frame Running sessions.[9] In brief, consent rates, retention rates, and outcome measure completion rates were calculated. We also recorded training attendance and any adverse events experienced during or after training sessions through athlete diaries and coach reports. Surrogate indices indicating cardiorespiratory fitness were assessed using the shuttle Frame Running test (SFRT) which is an adapted version of the shuttle run/walk tests (SRT) developed for children with CP.[14] The SFRT involved the participants proceeding between cones placed 10 meters apart around a 400m athletics track at an incremental speed determined by an auditory signal from a mobile phone app. Those participants who were able to complete 100m in less than 40s followed the auditory signals from GMFCS level I SRT protocol while others followed the GMFCS II protocol.[14] Participants also completed the 6-minute Frame Running test (6MFRT) during which participants were encouraged to cover as much distance on their frame within 6 minutes without stopping.[4,15] Frame Running endurance tests were separated by at least 7 days and were conducted as part of the participants' usual training session. To minimise infection risk post COVID-19 lockdown, we decided not to assess peak oxygen consumption (VO_2 peak) as originally outlined in the protocol.[9] We also did not conduct a full analysis of the participants' propulsion technique as described in the protocol.[9] Resting HR and systolic and diastolic blood pressure, isometric knee extensor strength using a myometer, and thigh, calf and waist circumference, using a tape measure, were measured at the track site for the participants at site B. Participants at site A were given the option to perform some of the study assessments at either the track before the training sessions or on a separate occasion at the University gait laboratory using the same equipment. Participants who came to the gait laboratory for the study assessments were offered reimbursement of their travel expenses. Study questionnaires included the Functional Mobility Scale (FMS) over 5, 50 and 500m;[16] EuroQol-5 dimension (Youth) (EQ-5D-Y);[17] the Psychosocial Impact of Assistive Devices Scale (PIADS),[18] and the Client Service Receipt Inventory (CSRI).[19] The Physical Activity Questionnaire for children (PAQ-C) was used to assess self-reported physical activity at baseline.[20] We assessed self-reported performance of activities of daily living activity and the satisfaction with this performance using the performance and satisfaction components of Canadian Occupational Performance Measure (COPM).[21] The semi-structured interviews for the COPM were conducted with the child/young person and/or parent present as appropriate. Similarly, the questionnaires were completed by the participants themselves, together with a parent or by the parent on behalf of the participant depending on the age and the cognitive ability of the participant. Daily step count was assessed using the activPAL4 (PAL Technologies Ltd, UK). Participants were asked to wear the monitor on the anterior aspect of the thigh on their least affected leg for 7 consecutive days. Participants with at least three valid days (i.e., out of bed wear time of at least 12 hours) were included in the analysis. To assess whether Frame Running training days resulted in a higher number of steps than other weekdays, we derived daily number of steps averaged over at least three non-Frame Running training day as well the number of steps taken on one training day. All study assessments at site A were undertaken by researchers with either a background in physiotherapy or exercise physiology and at site B by a MSc student in Sport and Exercise Science.

Data Analysis

Data are reported using descriptive statistics (i.e., frequencies, means and standard deviations)

The potential effects of Frame Running on continuous outcome measures were reported as estimates of effect (mean difference between outcomes at baseline and 12-week assessment) with 95% Confidence Intervals (CI).

Qualitative data collection

Participants

Participants who only took part in the qualitative part of this study were recruited through UK Frame Running clubs and social media. Young people aged 5 to 25 years, diagnosed with CP or another physical disability resulting in impaired mobility and balance, and who were currently or recently participating in Frame Running in the community were eligible to participate. Young people who were unable to understand and respond to interview questions in English (with or without the use of communication aids) were ineligible to take part. Parents of the athletes and other key stakeholders such as coaches and sports administrators who were involved in the implementation of Frame Running opportunities and able to communicate in English were eligible to participate in separate focus groups.

Interviews and Focus Groups

Data were generated through semi-structured interviews and focus groups via online video conferencing software (Microsoft Teams, United States). A parent was present for all interviews with athletes under the age of 16 years. All participants chose to join online interviews and focus groups with the video function. Interviews and focus groups were conducted by CE who is experienced in qualitative research methods and conducting interviews with children and young people. CE was independent to the Frame Running sessions and had no prior relationship with any of the participants. A second researcher (GA) acted as an observer and note-taker recording any non-verbal communication. Prior to data collection, GA had previous associations with some athletes, parents, and coaches. Topic guides were developed and revised by the research team to explore participants' experiences and perceptions of Frame Running. The topic guides (supplementary material 3) were adapted for each of the three participant groups. Interviews and focus groups commenced with several "ice-breaker" questions which were designed to build rapport and draw participants into the discussion (e.g., "other than Frame Running, what other activities did you do before lockdown?").[22] Before concluding interviews, participants were invited to add any further information they considered relevant but had not yet been discussed. Interviews and focus groups were audio-recorded and transcribed verbatim.

Qualitative Data analysis

Qualitative data were analysed abductively using concurrent inductive and deductive thematic content analysis.[23] Guided by a six-step process outlined by Braun & Clarke[23] analysis involved: 1) familiarization; 2) initial coding; 3) identifying themes; 4) reviewing themes; 5) defining themes; and 6) reporting. To safeguard anonymity, identifying information was removed with participants assigned pseudonyms. To create a clear understanding of the content and ensure familiarity with the data, interview transcripts were thoroughly read and re-read by two researchers (GA and GPM) before being imported into NVivo12 software (QSR International, UK) for initial coding. Following this, emerging themes transcripts were coded through line-by-line analysis of the transcripts with quotations assigned to categories of higher generality. Raw data units were then created from participants' words before being grouped into lower-order themes and then higher-order themes. This initial coding was data-driven in that lower-order themes were generated from the data itself. Deductive reasoning was subsequently employed to relate these back to the original research questions and generate higher-order themes, with this analysis being based upon two primary (facilitators and barriers) and four secondary themes (personal, social, environmental, and policy), based on the social ecological model described by Bronfenbrenner[24] *a priori* research themes. During analysis, internal homogeneity (data within a category share clear characteristics) and external heterogeneity (clear differences exist between different categories) was sought.[25] NVivo 12 and Microsoft Excel were used for data management.

Quantitative and qualitative data were collected independently and were compared at the stage of discussion, following a side-by-side comparison approach.[8]

Results

Quantitative Data

Recruitment and retention

The consort diagram (Figure 1) details the participant flow through the investigation. A baseline assessment was arranged for 35 out of 42 who met the inclusion criteria (83%). However, because of COVID-19 (n=9) and families unable to commit to regular Frame Running training sessions (n=3), only 23 provided consent (consent rate of 55%). The majority of the potential participants whose baseline assessment was cancelled due to COVID-19 were recruited through their schools where weekly Frame Running session would be offered. In Spring 2022 the government-imposed restrictions to reduce spread of COVID-19 were lifted sufficiently to allow outdoor activities such as Frame Running and the majority of the study protocols to re-start. However, special education schools were still very reluctant for external visitors (researchers, coaches) to come into the school, hence the majority of the potential participants before the pandemic could not be recruited to the study even when most restrictions were lifted. One participant stopped participating in Frame Running after 6 weeks because of conflicting demands from another sports activity (swimming) but attended all three study assessments. Characteristics of the participants who attended both the baseline and 12-week assessment are included in Table 1. Data collection occurred over a period of just over 3 years with the first participants recruited in December 2019 (pre COVID-19) and the last interview conducted in February 2023.

Insert Figure 1

Insert Table 1

Attendance and adverse effects

For the first 12 weeks training attendance was unavailable for two of the 15 participants. Because of a change in how attendance was recorded unfortunately, training attendance was not available for any of the 5 participants at site A for weeks 13-24. Median Frame Running training attendance during the first 12 weeks was 83% (mean 79%) ranging from 16% to 100%. Most common reasons for absence were family holidays and illness. Some training sessions in Scotland were also cancelled due to adverse weather (high winds and snow). No adverse events occurring during the training session were reported. Only one training diary was returned, with no adverse events noted.

Fidelity

Due to logistical reasons, HR during sessions was only recorded at site A and was available for 5 participants. Three of the 5 participants attained an average HR exceeding 65% of HR_{max}. throughout the training session. Illustrations of the HR profiles exhibited by each of these 5 participants during Frame Running sessions are available as supplementary material 4.

Outcome measure completion rates

Table 2 shows the outcome measures completion rates and reasons for missing data. Outcome measure completion rates ranged from 60% for 6MFRT to 98% for knee extensor strength (KEstr). Reasons for missing data included participants expressing discomfort and logistical reasons.

Insert Table 2

Description of quantitative outcomes

Table 3 shows means and standard deviations of the outcome measures at baseline and after 12 weeks of Frame Running training and the difference between these two assessments. Only the 95% CI for the change data of the knee extensor strength of the most affected leg (22% increase) did not include zero.

Steps taken on a Frame Running training day was on average 47% (std 30%, range 12%-86%) higher than the average daily step count across the three assessments points. Individual data for the outcome measures at 24 weeks are included in the supplementary material 5.

Insert Table 3

Stakeholders' perspectives and experiences regarding taking part in Frame Running

Ten athletes with moderate-to-severe walking impairments (6 females, 4 males, aged 6-20 years old, ≥2 years Frame Running experience) took part in interviews. Four parents (3 females, 1 male) took part in separate focus groups where the emphasis was on the impact of Frame Running on the parents themselves. Two focus groups were also conducted with in total of six coaches and one sports administrator (4 females, 3 males) with one to nine years of experience with Frame Running. The background of the coaches was in (para) athletics coaching (n=5), of which one a para-athlete themselves and paediatric physiotherapy (n=1). Interviews and focus groups lasted between 15 to 30 mins and 40 to 60 mins, respectively. All interviews and focus groups were conducted between July 2021 and February 2023.

Table 4 shows the four higher-order themes (personal, social, environment and policy factors) with corresponding lower-order themes and illustrative quotes.

Insert Table 4

Personal factors

Athletes and their parents reported a range of themes associated within this category highlighting their positive experiences with Frame Running such as the "sense of freedom" and "speed". Another theme was that Frame Running provides them with "an opportunity to be active" and "opportunity to compete" which other sports often do not provide. Athletes and parents discussed the theme of the role of "Frame Running as physiotherapy" and can thus take some of the burden off parents getting their children to do their exercises at home.

Social factors

Themes related to society/social factors were mostly seen as facilitators and included the "sense of belonging" both for athletes and their parents and the "inclusivity of Frame Running". The latter theme also referred to the experiences of other sports and structures not being so inclusive. Other themes were the importance of "athlete role models" and "word of mouth", for Frame Running to be more widely known, both by wider public and health care professionals such as physiotherapists. The latter group were regarded as instrumental in highlighting local Frame Running opportunities to their clients and their families.

Environmental factors

This category included themes such as “equipment” and “facilities” such as the issue of storing frames and “travel”. Another important theme in this category is the “adjustment of frames” to the athlete, especially if frames are shared by different athletes. Weather was also a common theme and was mostly discussed as a barrier. This theme also linked with the ‘facilities’ theme with indoor facilities often lacking for the colder and wetter winter months. Most of these themes were discussed as being barriers to Frame Running participation.

Policy Factors

“Frame Running classification” for athletes participating in competitions was a theme discussed in both athlete and coach groups. For example, the ineligibility of those with a non-neurological condition to participate in national and international competitions was highlighted as a barrier. We also included themes “financial challenges” in this category as frames can be expensive and “Frame Running coaches” relating to educating and recruiting Frame Running coaches. Within the theme “para sport governance” participants discussed the importance of volunteers and difficulties starting up a club while the theme “getting the message out there” related to initiatives and partnerships which could serve as facilitators.

Discussion

The aims of this mixed-method study were twofold: 1) to examine the acceptability, safety and perceived barriers and facilitators associated with taking part in Frame Running as a community- based exercise option and 2) to assess the feasibility of conducting a definitive study on the impact of Frame Running on cardiometabolic disease risk factors and functional mobility. Regarding the first aim, data revealed a median attendance rate of 83%, with no adverse effects, suggesting that Frame Running is an acceptable and safe community-based exercise option for the participants in this study. Reasons for non-attendance were primarily related to adverse weather conditions, an inherent challenge of Frame Running given the predominantly outdoor nature of the activity. The weather emerged as a recurring theme in the qualitative data, with some club training sessions pausing over the winter months. The attendance rates in our study are consistent with the 78-87% attendance rates reported by Soukal-Moulton et al,[7] for a study in which 7 of the 11 participants were provided with transportation to the Frame Running training sessions. The retention rate was also acceptable, with only three participants dropping out of the study with one further participant stopping with Frame Running but continuing to attend for data collection assessments (total of n=4, 17%). Dropouts were attributed to an inability to commit to weekly Frame Running sessions (n=3) possibly due to travel constraints, indicating a potential barrier to sustained participation (linking to the theme 'travel' in the qualitative data) and a focus on a different sport, possibly due to the absence of a clear elite pathway for Frame Running at the time of the study (linking to the theme of 'Classification'). Further, no serious adverse effects were reported, aligning with the relatively low injury rates reported in a recent survey of 115 Frame Running athletes.[26] Themes related to the acceptability of Frame Running primarily centred around enjoyment and encompassed lower-order themes such as 'speed', 'ability to compete', and 'independence' in the personal domain, along with 'inclusivity" and 'sense of belonging' in the social domain. These themes are indeed reflective of important facilitators for participation in physical activity and exercise among young people with CP and related conditions,[27,28] as well as in para sport in general.[29] While the aforementioned themes predominantly fall within the personal and social domains, relatively few studies have addressed themes within the environmental and policy categories, most of which were discussed as barriers. These themes, including 'equipment', 'adapting to the individual', "facilities', 'travel' and 'weather', as well as 'financial support', availability of 'Frame Running coaches' and 'para sport governance' are vital considerations for the feasibility and sustainability of any para sport opportunity.

Although the focus of the present study was on Frame Running, many of these themes are applicable to a range of para sports. For example, para sport coaches must understand how to adapt training to accommodate the often wide range of abilities and needs among participants. In some cases, it may be more appropriate to have groups or individuals doing a slightly different training session adapted to their needs and abilities. However, this scenario will often require an additional coach or volunteer.

Further, sports officials and policymakers should be aware of the importance of role models and word of mouth and connect with health professionals such as physiotherapists. There also seems to be a need to educate more mainstream sport coaches on para sport which should lead to more qualified coaches being available to work with para-athletes.

Although our study demonstrated support for the acceptability of Frame Running as a community-based exercise option, our assessment of the feasibility of conducting a definitive study on the impact of Frame Running on cardiometabolic disease risk factors and functional mobility may be regarded as less positive. Although partly due to the COVID-19 pandemic consent rate (55%) could be regarded as low. Logistical challenges present at the site B which recruited 10 of the 15 participants also meant that many outcome measures were only collected for the five participants at site A. Further, issues with pacing in performance tests over 6 minutes or longer such as 6MFRT especially in younger children may have led to relatively high measurement errors up.[30] Bolster et al.[4] reported that the Smallest Detectable Difference for 6MFRT was 146 and 167m for those at GMFCS levels III and IV respectively and recommended averaging the results of two repeated tests for increased reliability. Whilst the SFRT was also utilised to avoid pacing issues, this test presents its own challenges. These include the need to stop and start the rolling frame in the early phases of the test, the inability of some participants to perform at least one 'shuttle' (10 meters) in 18 seconds, difficulty maintaining speed due to motor impairments rather than cardiovascular factors, and the potential for the test to last as long as 21 minutes.

Preliminary evaluation of the quantitative outcomes

The quantitative data collected in this feasibility study such as the variation in outcome measures can be used to inform the design of future studies. Estimates of effect indicate that 12-weeks of weekly Frame Running session may improve knee extensor strength. Participants also noted improvements in their activity of daily living related performance. However, unlike the studies by Hjalmarsson et al.[5] and Sukal-Moulton et al.,[7] we did not observe an improvement in the 6MFRT. Possible reasons for this discrepancy could stem from our lower training frequency (i.e., once a week vs. twice a week) or the training content, which in our study was more focused on sprint (up to 200m) rather than endurance activities. In contrast, Sukal-Moulton and colleagues[7] included 20- to 30-minute endurance and pacing activities, while in the study by Hjalmarsson et al.,[5] participants performed long-distance intervals of 3-10 minutes during training.

Another reason for the lack of improvements in endurance may be that for some participants, Frame Running may not have provided an opportunity to exercise at sufficient intensity conducive to increase their aerobic fitness. This observation aligns with individual data reported by Hjalmarsson and colleagues,[5] where 5 of 15 participants also exhibited an average HR during the Frame Running session below 65% HR_{max}. It is possible that factors such as the presence of learning difficulties and severe levels of motor impairment in this population may have contributed to the lower training intensities achieved.

Strengths and Limitations

To our knowledge this is one of the first mixed-methods study reporting on a community-based exercise option that is also suitable for young people with moderate-to-severe mobility impairments. Participants in this study attended Frame Running sessions which were offered in the community rather than in a health care setting or as part of a study intervention that only lasted as long as the duration of the study. Further, to our knowledge this is one of the few studies that report on the feasibility of an adapted exercise option from a personal, social, environmental and policy perspective of athletes, their parents and coaches. Limitations of this feasibility study, which was affected by the COVID-19 pandemic, include the low sample size and the single group design which may limit the utility of the present findings to inform the design of future studies. We also did not collect data on peak oxygen uptake during the maximum performance tests due the risk of infection of COVID-19. We are therefore unable to comment on whether any changes in the 6MFRT or SFRT tests were due to changes in cardiorespiratory fitness, changes in Frame Running ability, or a combination of both. Edelman-Bos et al.[15] found a statistically significant correlation between peak oxygen uptake and the distance achieved in the 6MFRT. However, the suitability and sensitivity of the 6MFRT to assess improvements in cardiorespiratory fitness warrants further investigation. Finally, it should be noted that the barriers to Frame Running participation identified in this study, especially those linking to the 'personal domain' are relevant to those already taking part. It is likely that additional barriers exist that may prevent people from initiating participation. Future studies should focus on this group to fully understand the perspectives of those who chose not to participate.

Conclusions

The results of this mixed-method study underscore the acceptability and safety of Frame Running as an adapted exercise option for children and young people with walking impairments such as those living with CP. While the study primarily focused on outcomes related to cardiorespiratory fitness and functional mobility, qualitative data revealed common themes highlighting Frame Running as a unique activity for improving overall health and wellbeing. The study also sheds light on the social, environmental, and policy factors influencing the implementation and sustainability of Frame Running in the community. Results of this mixed- method study support potential benefits such as those on leg muscle strength and self-reported performance and satisfaction of activities of daily living, but future appropriately powered studies are needed to confirm this. Our data on consent rate, retention, session attendance outcome completion measures, and variability in outcome measures will inform the design of such studies.

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Alt Text

Figure 1 CONSORT flow diagram showing the process of enrolment, baseline and follow up assessments in two sites. The process started with the assessment of eligibility of 47 potential participants. Of those 12 were excluded for various reasons. A total of 35 participants gave consent to take part in the study (n=12 at site A, n=23 at site B). However, n=10 at site A and n=13 at site B attended baseline assessments, with the rest not being able to attend due to COVID-19 restrictions or lack of commitment to the Frame Running sessions. The 12-week assessment was attended by n=5 at site A and n=10 at site B, either due to COVID-19 restrictions or lack of commitment to the Frame Running sessions. Three participants attended the 24-week assessments at site A, whilst that was not applicable for site B.

Figure 1 CONSORT flow diagram of study enrolment and assessments at both sites.

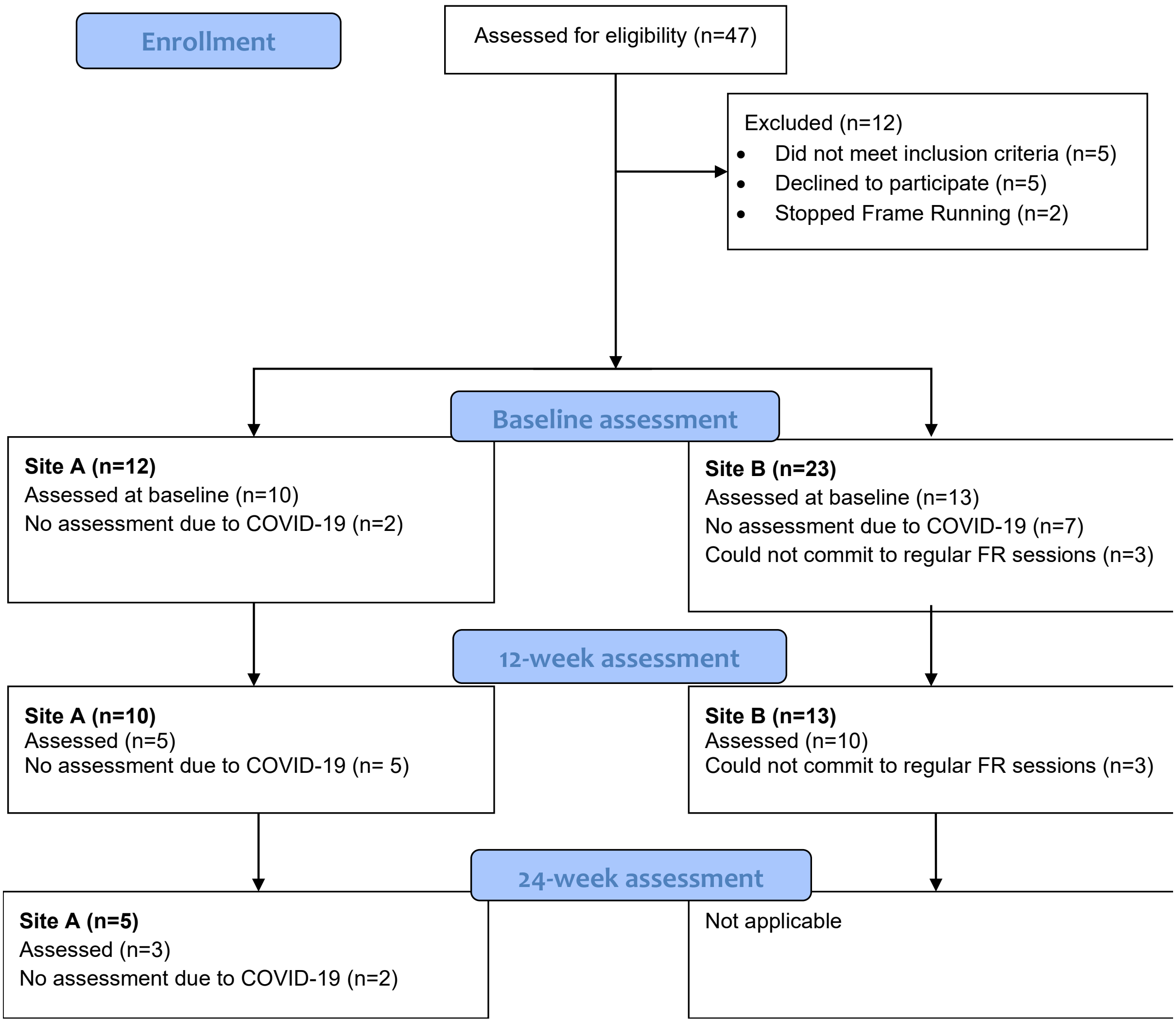

Table 1 Demographics for those who completed baseline (BL) and 12-week assessments (n=15).

	Mean (std); Median; Range
Age	12.9 (6.9); 10; 5-25
Male/female	8/7
Health condition	
• **CP**	12*
• **Acute flaccid myelitis**	1
• **Morquio Syndrome**	1
• **Not known**	1
Hemiplegia/Diplegia/Quadriplegia/dyskinesia/ataxia/NA	2/6/1/2/1/3
GMFCS (if CP) II/III/IV/NA	2/5/4/4
PAQ-C (min/week)	294(139); 255;90-480

*of which one with both CP and Spina Bifida

PAQ-C: Physical Activity Questionnaire, children's version.

Table 2 Outcome measure completion rates and reasons for missing data.

Outcome measures collected at both sites				
	Baseline (n=23)	**12W (n=15)**	**24weeks (n=4)**	**Reasons for missing data**
6 min Frame Running test	14/23	8/15	2/4	Logistical reasons, COVID-19 (BL)
Resting Heart Rate	20/23	12/15	2/4	Equipment failure, discomfort
Resting systolic blood pressure	20/23	12/15	2/4	Equipment failure, discomfort, arm cuff too big, COVID-19 (24w)
Resting diastolic blood pressure	20/23	12/15	2/4	Equipment failure, discomfort, arm cuff too big, COVID-19 (24w)
Knee extensor strength *	45/46	29/30	4/8	Not able/lack of understanding (BL); DNA (12w), COVID-19 (24w)
Thigh circumference*	44/46	28/30	4/8	Unknown (BL); DNA (12w); COVID-19 (24w)
Calf circumference*	42/46	26/30	4/8	Unknown (BL); DNA (12w); COVID-19 (24w)
Outcome measures only collected at sites A				
	Baseline (n=10)	12W (n=5)	24W (n=4)	
SFRT	5/10	4/5	2/4	COVID-19 (BL&24w); DNA
Oxygen consumption during SFRT	2/10	0/5	0/4	Oxygen uptake tests were removed from the protocol due to COVID-19 infection risk
ActivPal data	6/10	4/5	2/4	COVID-19 (BL); forgot or did not want to wear the monitor
PIADS	-	5/5	3/4	Questionnaire not returned
COPM	7/10	5/5	4/4	COVID-19 (BL)
FMS	6/10	5/5	4/4	COVID-19 (BL)
Eq5D VAS	7/10	5/5	4/4	COVID-19 (BL)
CSRI	5/10	4/5	3/4	Questionnaire not returned
%Fat free Mass	8/10	4/5	2/4	COVID-19 (BL&24w) did not like stickers attached to skin, DNA
Waist circumference	7/10	4/5	2/4	COVID-19 (BL &24W); wearing orthotic vest; DNA

*Data for both legs
COVID-19 (BL); not all data collected in one visit, no further visits arranged because of the COVID-19 lockdown; COVID-19 (24w): only questionnaire data collected, no performance measures due to COVID-19 lockdown; DNA: Did not attend assessment; SFRT: Shuttle Frame Running test; FMS: Functional Mobility Score; PIADS: Psychosocial Impact of Assistive Devices Scale; COPM: Canadian Occupational Performance Measure; Eq5D VAS: EuroQol-5 dimension Visual Analogue Scale; CSRI: Client Service Receipt Inventory.

Table 3 Mean values (standard deviation) and range of outcome measures at the baseline (BL)and 12-week (12w) assessments. The last column includes the mean change (95% CI) and % change for those participants for whom data for both assessments were available.

		Mean(std); range	12 week- BL Mean change [95% CI] (% change)
HRrest(b/min)	BL (n=20)	94(15);66-121	-6 [-13:1] (-7%)
	12w n=12)	83(12);65-110	
BPsys (mmHg)	BL (n=20)	121(21);95-169	3 [-1:7] (+2%)
	12w(n=12)	125(23);95-172	
BPdias (mmHg)	BL (n=20)	78(17);46-109	-1 [-13:11] (-2%)
	12w(n=12)	80(22);46-125	
6MFRT (m)	BL (n=14)	807(384);131-1345	-71 [-180:35] (-9%)
	12w (n=8)	738(367);121-1243	
KEMA (Nm)	BL (n=21)	92(62);9-257	25 [3:47] (+22%)
	12w(n=13)	117(99);28-328	
KELA (Nm)	BL (n=22)	120(82);18-303	11 [-8: 29] (+8%)
	12w(n=15)	137(101);31-349	
CalfccMA(mm)	BL (n=20)	28(7);19-49	1 [-0.1:2] (+3%)
	12w(n=13)	29(6);19-29	
CalfccLA (mm)	BL (n=20)	29(6);20-40	0.2 [-0.4: 0.7] (1%)
	12w(n=13)	30(6);20-40	
ThighccMA(mm)	BL (n=21)	39(12);26-65	1 [-1:3] (+3%)
	12w(n=14)	39(11);25-58	
ThighccLA(mm)	BL (n=21)	41(12);27-66	0.3 [-2:3] (1%)
	12w(n=14)	39(11);25-59	
SFRT (shuttles)	BL (n=5)	7.9(6.4);1-17	0.6[-1.7:2.9] (+7%)
	12w (n=4)	8.7(8.4);1.6-19	
Fat free Mass (%)	BL (n=7)	79(9);70-97	1.9[-3.2:7.0] (+2%)
	12w (n=4)	75(1);73-76	
Waist circumference (mm)	BL (n=7)	61(6);54-72	0.7 [-3.2:4.5] (+1%)
	12w(n=4)	62(11);54-76	
ActivPal data (steps)	BL (n=6) 12w (n=4)	4870(4742);368-11042 7489(7122);468-17415	1768[-8117:11689] (+36%) (based on n=3)
PIADScomp [-3 :-3]	12w (n=5)	1.58(1.0); 0.09-2.8	-
PIADSadapt [-3 :-3]	12w (n=5)	1.6(0.9); 0.2-2.5	-
PIADSse[-3 :-3]	12w (n=5)	1.4(0.6);0.88-2.38	-
COPMp [0-10]	BL (n=7)	5.4(2.2);1.9-8	1.3[-0.6:3.1] (+23%)
	12w (n=5)	7.0(2.0);5.1-9.7	
COPMs [0-10]	BL (n=7)	4.5(2.3);1.8-9.0	2.1 [-2.1:6.2] (+46%)
	12w (n=5)	7.0(2.2);3.8-9.3	
Eq5DVAS [0-100]	BL (n=7) 12w (n=5)	71(26);30-98 88 (16);60-100	20 [-7:49] (+28%)
FMSmean(1-6)	BL (n=6)	2.8(1.5);1.0-4.7	0.12 [-0.2:0.5] (+4%)
	12w (n=5)	3.3(1,2);1.7-4.7	

HRrate: resting heart rate, BPsys: Systolic Blood pressure; BPdias: Diastolic Blood Pressure, 6MFRT: 6-minute Frame Running test; MA most affected leg, LA: least affected leg. KE: Knee extensor strength; Calfcc: Calf Circumference, Thighcc: Thigh Circumference, COPMp: Canadian Occupational Performance Scale-performance component; COMPs: Canadian Occupational Performance Scale Satisfaction Component; FMS: Functional Mobility Score; PIADS: Psychosocial Impact of Assistive Devices Scale. Comp: competence; Adapt: adaptability; SE: Self-efficacy; Eq5D VAS: EuroQol-5-dimension Visual Analogue Scale

Table 4 Personal, social, environmental and policy factors influencing the initiation, promotion, and sustainability of Frame Running opportunities within the community.

Personal factors	
Theme	Example quote
Opportunity to compete (athletes, n=9; parents, n=3; coaches, n=3)	*"Yeah, I'm naturally a quite competitive person, and I really enjoy that aspect of it, the going to competition and competing against other people"* (Athlete A)
	"They've had the opportunity to do some athletics meets, just like an able-bodied person would, and I think that just gives them that sense of I'm doing something similar" (Parent A)
	"What we've found is we've had the ones that really want to come and compete and they kind of make up one group" (Coach A)
Opportunity to be fit, active, and healthy (athletes, n=5; parents, n=4; coaches, n=2)	*"Um I just like running and getting some exercise because well I can't really do it in any other way, so I can do it that way"* (Athlete B)
	"I think it's important for her to keep going…she needs to be on her feet. She needs to keep her strength up. It's really important that she does something to keep her legs strong" (Parent D)
	"It became about getting people active and providing an opportunity that they could do" (Coach B) "*Yes, I think we've certainly seen improvement in things like muscle tone and things like that, and in X legs" (Parent C).*
Frame Running as physiotherapy (athletes, n=6; parents, n=2; coaches, n=1)	*"I had just gone through two hip replacement surgeries. So, we were looking for ways for me to be able to stay active while still being able to recover from those major surgeries"* (Athlete A)
	"He was struggling medically and physically and whatever, and he had different surgery last year that gave him the potential to start building his strength up and Frame Running has been a big part of that" (Parent C) *"…, it took pressure of us, 1 day a week not having to think of all that physio type stuff because they were getting a lot of it at the training session, so it was actually a release (*Parent A*)*
Sense of freedom (athletes, n=4; parents, n=2; coach, n=1)	*"I feel safe and can go as fast as I want and when I'm running without the bike I think I'm not safe and I know that I can fall over"* (Athlete C)
	"As soon as he went on the frame…he experienced something he never experienced before which was speed and independence" (Parent A)
	"It's more than just about a sport. It's about freedom and independence" (Coach A)
Speed (athletes, n=3; parents, n=1)	*"Because I can be like everyone else. Because everyone runs, I can't run as fast as them, but when I am on the RaceRunner I can!"* (Athlete D)
	"The thing he found the first time he went on the racerunner was that they could go fast and he could determine the speed he was going at" (Parent A)

Release from the stresses of life (athletes, n=1)	*"When I'm running I obviously don't think of it, the stuff you would normally think about if you were doing day to day things if you know what I mean, so you're not really thinking about stuff, you were concentrated on running, so it's kind of like a break from that as well"* (Athlete B)
Fatigue (athletes, n=1)	*"You feel tired at the end and sometimes my…like until the end so I get dinner so then I'm hungry"* (Athlete E)

Social factors	
Theme	Example quote
Sense of belonging (athletes, n=9; parents, n=4; coaches, n=1)	*"I like to run with my friends I've made there, so I enjoy going so I can see them"* (Athlete B)
	"It's not just the athletic part of it. For us, one of the big things is also the social aspect of it where you're going along, you're included as part of a group or a club" (Parent C)
	"It's lovely to see those kids belong to a club…one of my most touching moments was when we gave them all hoodies and one boy said I've never had a hoodie, I've never belonged to a club" (Coach C)
Inclusivity – a sport for everyone (athletes, n=5; parents, n=3; coaches, n=6)	*"It's not just for the elite athletes. It's for everybody, of all abilities"* (Athlete I)
	"And then just before she started Frame Running, she was trying a few different sports and wasn't able to take part. And when you first went to Frame Running and then she was coming home and saying that she really liked that there was a sport that she could do just as much as everyone else" (Parent D)
	"It's here for anybody who wants to come and try it" (Coach A)
Role models (athletes, n=4; parents, n=2)	*"I enjoy because the RaceRunning champion broke the world record on the track [where I train] a couple of months ago, so I enjoy being where athletes have been"* (Athlete D)
	"One of her coaches, she's a Paralympian. So, that's quite good having her there because it gives the kids a bit of a boost seeing somebody that's gone through the same as them so she's quite influential in that way" (Athlete J)
Word of mouth (athletes, n=6; parents, n=2; coaches, n=2)	*"The world champion messaged me after seeing one of my videos on YouTube about being bored and being stuck in the house, so she emailed me saying we've got a group based in xxx if you want to come and try"* (Athlete A)
	"We were introduced to RaceRunning through his specialist physio" (Parent A)
	"We went down the route of putting the word out through physiotherapists" (Coach C)

Environmental factors	
Theme	Example quote

Equipment athletes, n=7)	*"We're fortunate that we have the use of the frame at home. We transport it back and forwards, so we can use it, you know, throughout the week"* (Athlete E) *"We're also looking at trying to build fleets of them in our schools, so that children can use them for sports days or lunchtime or PE"* (Athlete G)
Facilities (athletes, n=2; parents, n=2; coaches, n=4)	*"yeah whereas, whereas I don't know of any others nearby. yeah or near us at all. there are wonderful racetracks …., down the road, which it would be wonderful to be able to use, you know to utilize those."* (Parent D) *"Storage is a big issue. They do take up quite a lot of space. We've got quite a lot of frames and are working on squashing them into quite a small space"* (Coach A)
Travel (athletes, n=5; parents, n=4; coaches, n=2)	*"I mean, it's a half hour trip there and a half hour trip back so it eats into the time and so I don't know whether that puts them off"* (Athlete D) *"The other thing that's possibly worth mentioning is the logistics of travelling around with the frame as well…because it's quite a big piece of kit"* (Parent D) *"From my experience anyway, the people that are coming, they've got very supportive families who are willing to drive them great distances to get to training"* (Coach D)
Weather (athletes, n=3; parents, n=1; coaches, n=4)	*"Over the winter, both training are outside and that's why I'm not doing it, I get so bored"* (Athlete A) *"I think it's hard as well because it's quite cold and wet. So, it's kind of difficult when it's cold and wet to motivate yourself to go out there and do that for an hour"* (Parent D) *"Over the winter as well, there's not really facilities indoors, so that's when a lot of people can fall away. And then they just don't come back, which is a shame"* (Coach D)
Adjustment of frames (athletes, n=9; parents, n=2; coaches, n=2)	*"The issue is if it's not your RaceRunner, it won't necessarily be suited to you. So, like if you're quite a tall person and then a short person comes in, you'll have to spend time adjusting it"* (Athlete A) *"And so, we were finding we were spending quite a lot of the session getting the set-up right"* (Parent B) *"If someone else comes in to go on that bike, then it's going to take you a good 20 minutes, half an hour to set it up exactly how it needs to be for that next person. So, that takes away a lot of time"* (Coach A)
Policy factors	
Theme	Example quote
	"That, for me, is one of the major downsides to RaceRunning because essentially I'm not a classified RaceRunner. So, I can compete in regional competitions, but I can't go any further than to like national, international competitions" (Athlete A)

Classification (athletes, n=2; parents, n=1; coaches, n=3)	*"I think for my eldest son, the biggest barrier to being able to go competitively as far as he wants is the fact that at the minute his disability is outside the classification system"* (Parent B) *"It's very complicated because of the individuality of everybody's abilities"* (Coach A)
Financial challenges (athletes, n=2; parents, n=1; coaches, n=5)	*"The price of frame runners needs to be lowered, because at the minute, it's not cheap to get a race runner for yourself"* (Athlete A) *"It is quite expensive. Three grand for a frame then the spikes cost a lot, then it's like £10 a month for the club"* (Parent D) *"And then I suppose the cost is something that add up on top of the other challenges"* (Coach E)
Frame Running Coaches (parents, n=1; coaches, n=5)	"*There is no like courses that look at disability coaching. Not that I'm aware of. ….. There's nothing up here, so like how can you get people involved in disability coaching if there's no education into it so? Yeah*." (Coach F) *"I think is has to be the right people. Just because you're a qualified level 2 coach doesn't mean that you're going to be a good coach in frame running. You have to be a certain type of person with a certain type of understanding"* (Coach A) "*I don't understand why there is a reluctancy from coaches and move into para athletics. ….. but I, I suspect this is sort of some uhm silent fear about working with people with disabilities*". (Coach B)
Para sport governance (parents, n=2; coaches, n=4)	*"It's making sure there's enough people to help out with the group, ……. These people have maybe higher impairments and maybe more individual needs, you probably need a bit more one to one or more coaches involved"* (Coach F) "*When we started as a club, we had a little bit difficulty starting it up because we approached disability sports… and they were not keen taking this on be cause they felt it was too much of a problem, storing the frames, getting the frames*" (Coach C) "*we have a lot of great volunteers at the club which is brilliant …..I suppose the volunteers aren't necessarily there for the development of the athletics, they're there to support the people*" (Coach E)
Getting the message out there (parents, n=2; coaches, n=4)	*"Our local athletics track hosted an inclusive sports day turn up and have a go and then they were starting to run sessions"* (Parent A) *"It's trying to recruit people, but I guess it's probably making it more known that there's a sport for people with these disabilities that you can join in and you can be independent"* (Coach F) *"That's one of my goals is to make mainstream school PE more inclusive for disabled students and if race running can be part of that, that would be good"* (Parent B)