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Original Article

Clinical use of blood flow restriction in people with neurologic conditions: a cross-sectional survey

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Abstract. [Purpose] There is little evidence for blood flow restriction (BFR), or Kaatsu, training in people with neurologic conditions. This study's purpose was to survey clinicians on BFR use in people with neurologic conditions. [Participants and Methods] One-hundred twelve physical therapists and other healthcare professionals who reported using BFR in the past 5 years completed an anonymous, online survey. [Results] Eighty-nine percent of respondents thought BFR was safe in people with neurologic conditions. Meanwhile, 38% reported BFR use in people with neurologic conditions. The most common intervention used with BFR was resistance training (n=33) and the most commonly reported benefit was improved strength (n=27). The most common side-effect causing treatment to stop was intolerance to pressure (n=6). No side-effects requiring medical attention were reported. In order to support future BFR use in neurologic populations, the most common response was the need for more research (n=63). [Conclusion] Despite the lack of evidence, clinical use of BFR in people with neurologic conditions may be somewhat common. Although this study had a relatively small sample size and collected data retrospectively, the results support the potential clinical feasibility and safety of BFR use in patients with neurologic conditions and suggest that more research is needed.

Key words: Blood flow restriction, Kaatsu training, Neurologic conditions

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INTRODUCTION

Exercise training with blood flow restriction (BFR), or Kaatsu training, is an increasingly common clinical intervention among physical therapists and other medical and/or exercise professionals[1)]. BFR training uses an external cuff to partially occlude arterial blood flow and completely occlude venous return of an exercising limb, inducing tissue hypoxia and triggering a cascade of events including anaerobic metabolism, protein synthesis, and satellite cell proliferation[2, 3)]. As a result, low intensity resistance training with BFR (20–30% of 1-repetition max [1RM]) can be as effective at increasing muscle strength and mass as high intensity training without BFR (70–80% of 1RM) in people with musculoskeletal conditions[3–5)]. In addition to resistance training, BFR has been shown to improve muscle performance and aerobic capacity during aerobic exercise[6, 7)]. and has even been studied passively in an effort to prevent muscle atrophy[8, 9)]. Until recently considered a novel treatment,

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the clinical application of BFR has grown widely over the past decade or more, and consistent with the evidence, is most commonly applied by clinicians in order to increase muscle mass and strength following musculoskeletal injury[1].

Moderate-to-high intensity exercise can be important for people with neurologic conditions and can lead to improvements in strength and mobility[10]. However, training at lower intensities using BFR has the potential to be an important intervention for people with neurologic conditions as it can be easier to tolerate than higher intensity training while still resulting in similar physiological and performance gains[2, 11]. Nevertheless, few studies have investigated BFR training in people with neurologic conditions and therefore less is known about safety, feasibility, or efficacy in these populations. There is preliminary evidence supporting the safety and feasibility of exercise training with BFR in people with a limited range of neurologic conditions such as cerebral palsy (CP)[12], inflammatory myopathies[13–17], multiple sclerosis (MS)[18–20], Parkinson disease (PD)[21], and spinal cord injury (SCI)[22, 23]. However, due to the relatively strong body of evidence for BFR training in musculoskeletal conditions and the proliferation of use in recent years[1], it is likely that clinical use of BFR has expanded beyond only individuals with musculoskeletal conditions.

Collecting early data on the real-world, clinical application of BFR in people who have neurologic conditions would be an important first step in estimating the frequency of BFR use in these populations. In addition, capturing data on clinical BFR use in people with neurologic conditions could also provide preliminary insight into its safety, tolerance, and feasibility. Furthermore, it is important to understand how clinicians who have used BFR in people with neurologic conditions report making their decisions to use BFR considering the lack of evidence. Finally, understanding real-world application, clinical decision-making strategies, and practitioner perspectives on the future direction of BFR research in people with neurological conditions will guide the clinical utility of future research[24].

Therefore, the primary objective of this study was to describe the frequency of blood flow restriction training application in people who have neurological conditions as reported by practitioners using an electronic survey. In addition, we identified side-effects and benefits, exercise selection, clinical decision-making strategies, and future needs related to BFR use in people with neurologic conditions. We hypothesized that ≥25% of respondents would report using BFR in at least one patient with a neurologic condition, that BFR would be perceived as safe and effective, but that limited evidence would be a barrier for application.

PARTICIPANTS AND METHODS

This cross-sectional study collected data with an anonymous, electronic survey approved by the Colorado Multiple Institutional Review Board. Separate approval was not sought through Europe's General Data Protection Regulation system due to different consent requirements and definitions of personal data, therefore those living in Europe were excluded from the study. Consent and screening questions were embedded in the questionnaire. Adults who self-identified as exercise and/or medical professionals and reported using BFR as part of their practice in the past 5 years were eligible to participate. Potential participants were excluded if they reported not using BFR training in their practice. Participants who were excluded or did not consent were not able to access the survey.

All survey responses were collected through an anonymous public survey link and data were stored in a secure REDCap database. The survey was distributed via listservs, social media, online message boards, and professional networks. Snowball sampling was encouraged to maximize response. A standardized script was used during the initial distribution that explained the study purpose and eligibility criteria. No protected health information or other unique identifiers were collected.

The survey was developed by the study team and pilot tested on four practitioners who had experience with BFR in neurological conditions. The survey consisted primarily of close-ended, multiple choice, and Likert-scale questions. The survey was divided into five sections that used branching logic based on whether respondents had used BFR in people with neurologic conditions or not. The first survey section was used to characterize the sample: all participants were asked to report general, standard non-identifying information such as age, gender, level of professional training, practice setting, and location. Finally, regardless if they had used BFR or not in neurological populations, all participants were asked if they thought BFR was generally safe in these populations.

The second and third survey sections appeared only to those who reported using BFR in at least one patient with a neurologic condition. In section two, respondents were asked to identify if they had used BFR in any of the following common neurologic conditions: amyotrophic lateral sclerosis (ALS), CP, inflammatory myopathies (e.g Inclusion Body Myositis, polymyositis, etc.), MS, muscular dystrophies, PD, SCI, stroke, and traumatic brain injury (TBI). Respondents could also list "other conditions". Respondents who reported using BFR in people with neurologic conditions were also asked to answer questions regarding patient level of function, goals, and exercise type, dosing, frequency, and intensity. The third survey section asked about side-effects and benefits related to BFR application. Side-effects were categorized into "serious" (interrupted the session, may have caused discontinuation of BFR, and/or resulted in the need for additional medical care) or "not serious" (may or may not have interrupted the session, did not cause discontinuation of BFR, and did not result in the need for additional medical care).

Participants who reported having a caseload including people with neurologic conditions were presented with section four of the survey, which presented a series of questions regarding their use of the evidence, clinical judgment, and patient values when deciding whether or not to use BFR. All respondents were asked to complete section five, which asked about

comfort level with future application of BFR in neurologic conditions and future needs that could potentially support clinical decisions of whether or not to use BFR in people with neurologic conditions.

The goal of the survey was to collect a minimum sample of 100 respondents with the hypothesis that at least 25 would report using BFR in neurologic conditions. Descriptive statistics and narrative summaries were used to characterize the sample and describe the data. All responses were recorded for anyone entering the survey. Surveys were considered for data analysis only if section one of the survey was completed. Partially completed surveys for the remainder of the sections were considered in an effort to capture as many responses as possible. Descriptive statistics were analyzed using SPSS Statistics 27 (IBM, Armonk, NY, USA).

RESULTS

From May 10, 2021 to June 10, 2021, 133 people accessed the survey online. Of those, 21 (16%) were not included in the analysis (6 did not complete any information, 9 were not eligible, and 6 did not complete section one), leaving 112 final survey respondents. Of the 112 final respondents, the mean age was 40.0 ± 9.7 years, 75% identified as male, and the majority were Caucasian (91%) and non-Hispanic (93%). All 112 respondents were from the United States, representing 33 states and the District of Columbia. The majority of respondents reported being physical therapists or physical therapy assistants (80%). The most commonly reported practice settings were private practice (55%) followed by hospital-affiliated outpatient (24%) clinics. While 74% of respondents reported that at least some of their caseload consisted of patients with neurologic conditions, only 18% reported having a caseload where more than 10% of their patients had neurologic conditions. Still, 89% reported they thought BFR was generally safe in neurologic conditions, 11% were unsure, and no one responded that they thought it was unsafe. Finally, 43 respondents, or 38%, reported using BFR in at least once in a person with a neurologic condition. Table 1 contains sample characteristics.

Of the 43 respondents reporting prior BFR use in people with neurologic conditions, the median number of unique patients where BFR was used was 3 (range 1 to 40). The majority of these patients were walking independently (n=33), followed by use of a unilateral assistive device (n=15), bilateral assistive device (n=9), and power or manual wheelchair (n=6). BFR was most commonly applied with patients who had conditions of MS and SCI (n=13). The most common patient goals were to improve strength (n=32) and activities of daily living (n=26, Fig. 1).

The most common exercises used with BFR were resistance training (n=33) and aerobic training (n=20, Fig. 2). During resistance training, dosing was most often based on perceived rate of exertion/fatigue (n=22), observed form fatigue (n=21), or patient-reported tolerance (n=21). Only 6 respondents reported dosing based on 1RM. For all other forms of training besides resistance, dosing was primarily based on patient-reported fatigue (n=19), followed by observed form fatigue (n=15), and patient-reported tolerance (n=13). Regardless of exercise type, limb occlusion pressure (LOP) was most frequently set at 71–80% maximal LOP (n=30) and the most common plan of care was twice weekly visits (n=26) for 6 weeks (n=22). See Supplementary Table for dosing and frequency details.

Of the 43 respondents reporting prior BFR use in people with neurologic conditions there were not any serious side-effects reported that required medical attention. The only side-effects reported that resulted in clinicians stopping BFR treatment altogether were severe lack of tolerance to pressure (n=6), severe fatigue (n=5), severe pain (n=4), and severe muscle soreness (n=3). Minor side-effects that did not result in stopping BFR as an intervention were more frequent: the most common being muscle soreness (n=14) and lack of tolerance to pressure (n=13). The most commonly reported benefits were improved muscle strength (n=27) and decreased fatigue (n=21). Only one respondent reported no benefits from BFR. Figure 3 lists side-effects and benefits.

All respondents were asked about their use of the evidence as to whether or not to use of BFR in their patients with neurologic conditions. Those that ultimately decided to use BFR reported their top reasons were evidence from a non-neurologic population (n=21) followed by evidence in their patient's neurologic condition (n=17). For those that did not end up using BFR, the top reasons were lack of evidence (n=20) and the strength of evidence (n=9) to support BFR use. When considering clinical judgement, the survey respondents reported that asking peers who had previously used BFR in people with neurologic populations (n=16) and the lack of success with other treatments (n=12) as the top reasons for supporting their decision to use BFR. For those that did not end up using BFR, the top reason was that other treatments were already effective (n=25), followed by lack of experience using BFR in people with neurologic conditions (n=11). When considering patient input, the top reason supporting BFR use was presenting it to patients as a treatment option (n=32) followed by the patients asking specifically to use BFR (n=7). For those that did not end up using BFR, there was most frequently no conversation with the patient about BFR use (n=23) although some patients also reported previously trying and not tolerating BFR (n=4).

Eight-six respondents completed the final section (Section 5) of the survey, 33 (38%) of whom reported using BFR in people with neurologic conditions (40.7 ± 9.9 years old, 76% male, 78% physical therapists/physical therapy assistants). Of these 86 respondents, 73 (85%) reported that, if they had access to patients with neurologic conditions in the future, they would be somewhat likely (n=23) or very likely (n=50) to use BFR. Ten reported they would be undecided, and 3 reported they would be very unlikely to use BFR. Assuming access to future patients, respondents reported they would be most comfortable implementing BFR with people who had SCI and stroke (n=48) and PD (n=47), and least comfortable using BFR with people who had ALS (n=39) and muscular dystrophy (n=23). In order to support future decision making, respondents

Table 1. Descriptive characteristic of study sample (n=112)

Age (years), mean ± SD	40.0 ± 9.7
Gender, Female (%)	28 (25%)
Race/Ethnicity	
Caucasian	102 (91%)
Non-Hispanic	104 (93%)
Profession (Select as many as apply)	
Physical therapist/PT assistant	89 (80%)
Athletic trainer	29 (26%)
Certified strength & Conditioning specialist	15 (13%)
PhD/EdD/DSc	3 (3%)
Chiropractor	2 (2%)
Certified exercise physiologist	1 (1%)
Medical doctor/Physician assistant	1 (1%)
Occupational therapist/OT aassistant	1 (1%)
Other	2 (2%)
Practice setting (Select as many as apply)	
Private practice (non-hospital affiliated)	61 (55%)
Hospital-affiliated outpatient clinic (non-VA)	27 (24%)
Sports team (professional, collegiate, or amateur)	24 (21%)
Academic/Research setting	11 (10%)
Military/VA outpatient clinic	7 (6%)
Hospital inpatient setting (non-VA)	4 (4%)
Health club/fitness facility	3 (3%)
Military/VA inpatient setting	0 (0%)
Other	6 (5%)
Time using BFR as part of practice	
<1 year	4 (4%)
1–3 years	58 (52%)
3–5 years	35 (31%)
5–10 years	15 (13%)
BFR safety in people with neurologic conditions	
Yes, it is generally safe	100 (89%)
Unsure if it is safe or not	12 (11%)
No, it is not generally safe	0 (0%)
Percent of people with neurologic conditions on caseload	
None	29 (26%)
1–10%	63 (56%)
11–25%	14 (13%)
26–50%	2 (2%)
>50%	4 (4%)
BFR use in ≥1 patient with a neurologic condition	
Yes	43 (38%)
Unsure	69 (62%)

BFR: Blood-flow restriction; VA: Veteran's affairs.

to the final section reported the top areas where they would like to see more BFR research would be in people with SCI (n=50) and stroke (n=49). The primary type of research respondents wanted to see was efficacy/effectiveness research (n=74) followed by safety research (n=61). While research was the top need that respondents reported in order to support future BFR use in people with neurologic conditions (n=63), the next most common responses were more experience/training (n=49) and continuing education (n=28). Figure 4 details comfort level of BFR use and future needs.

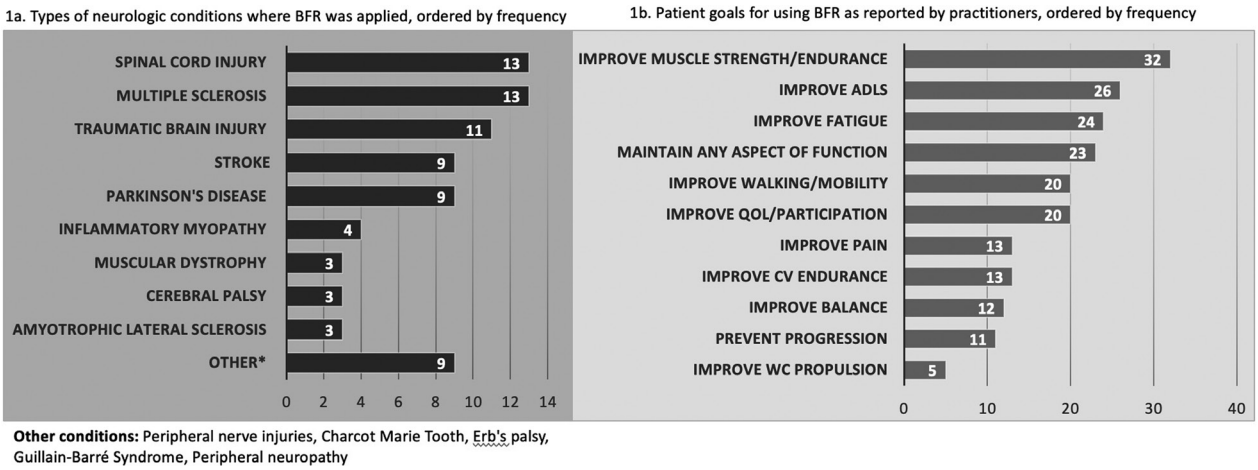

Fig. 1. Types of neurologic conditions treated using blood-flow restriction (BFR) (1a) and patient goals for using BFR (1b).

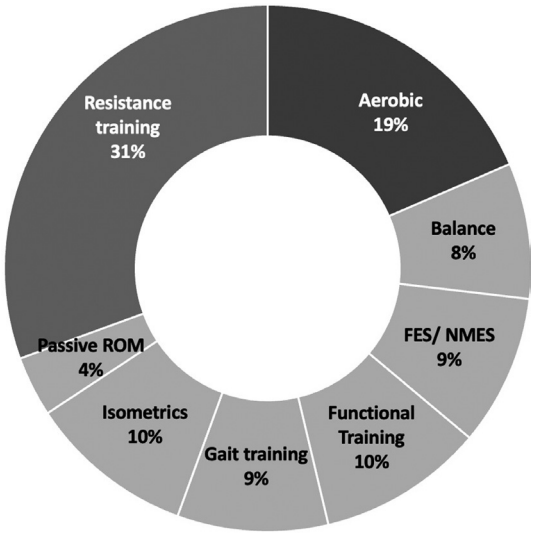

Fig. 2. Frequency of exercise selection during blood-flow restriction (BFR) application in people with neurologic conditions.

DISCUSSION

This study surveyed clinicians who use BFR as part of their practice and found that BFR use in people with neurologic conditions was relatively common. In this study, BFR was most frequently implemented during resistance training in people who were ambulatory. Survey respondents did not report any serious side-effects requiring medical attention, and although a variety of minor side-effects were reported, BFR was overall perceived to be safe and beneficial. Finally, survey respondents indicated that they would like to see more research and training in order to support future use of BFR in people with neurologic conditions.

The sample in this study consisted primarily of physical therapists and physical therapy assistants. This is in contrast to a recent survey on BFR use by Patterson and Brander[1)], where the most represented clinicians were strength and conditioning coaches (40%). Patterson and Brander[1)] did not report on BFR use in neurologic populations, but physical therapists may be more likely than other exercise professionals to work with patients with neurologic conditions, and possibly the current study enrolled a higher proportion of physical therapists due to their interest in the topic. Therefore, while a selection bias may have overestimated actual BFR use in a wider range of professions, the survey results may be especially helpful for physical therapists and rehabilitation researchers currently using or considering the use of BFR in people with neurologic conditions.

Respondents to the current study reported using BFR most frequently with people who had MS and SCI, two conditions where there is preliminary evidence supporting the feasibility of BFR[18–20, 22, 23)]. In contrast, respondents also commonly reported BFR use in people with stroke and TBI, but to our knowledge, there are no peer-reviewed studies examining BFR

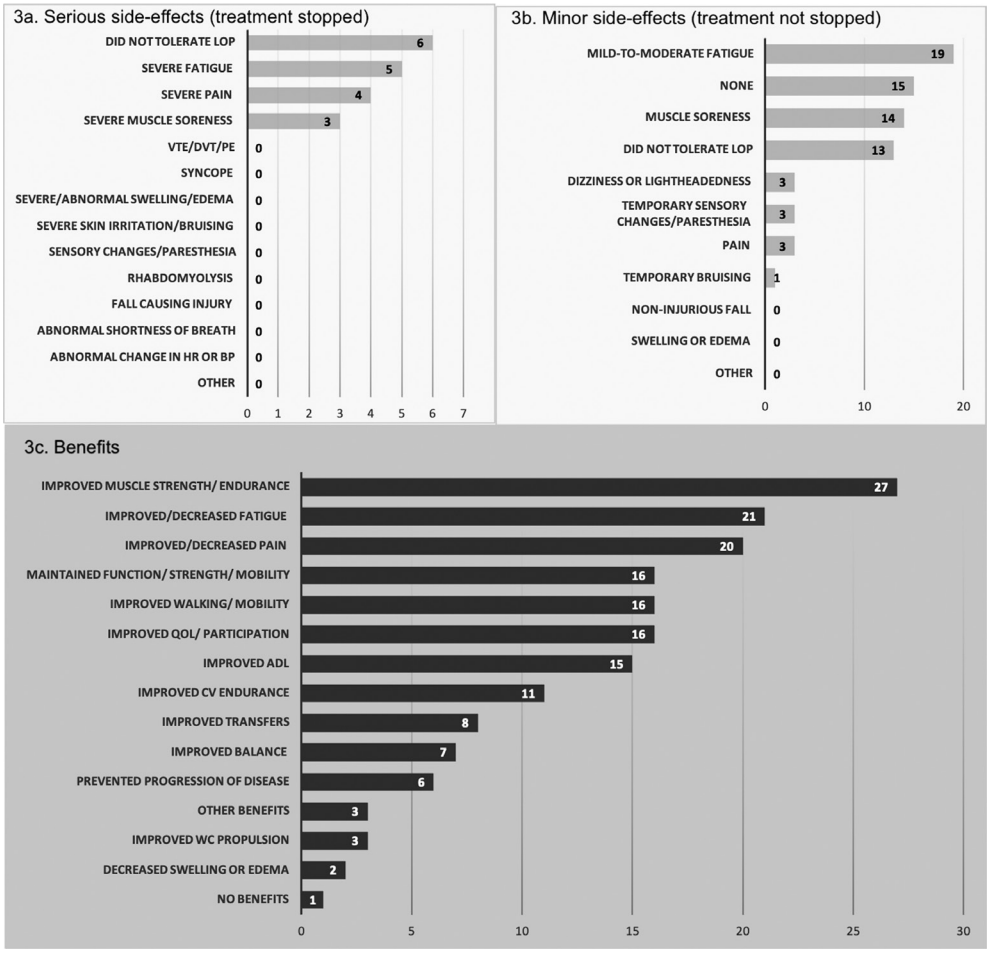

Fig. 3. Severe side-effects that caused blood-flow restriction (BFR) treatment to stop (a); minor side-effects that did not cause treatment to stop (b); benefits of BFR (c).

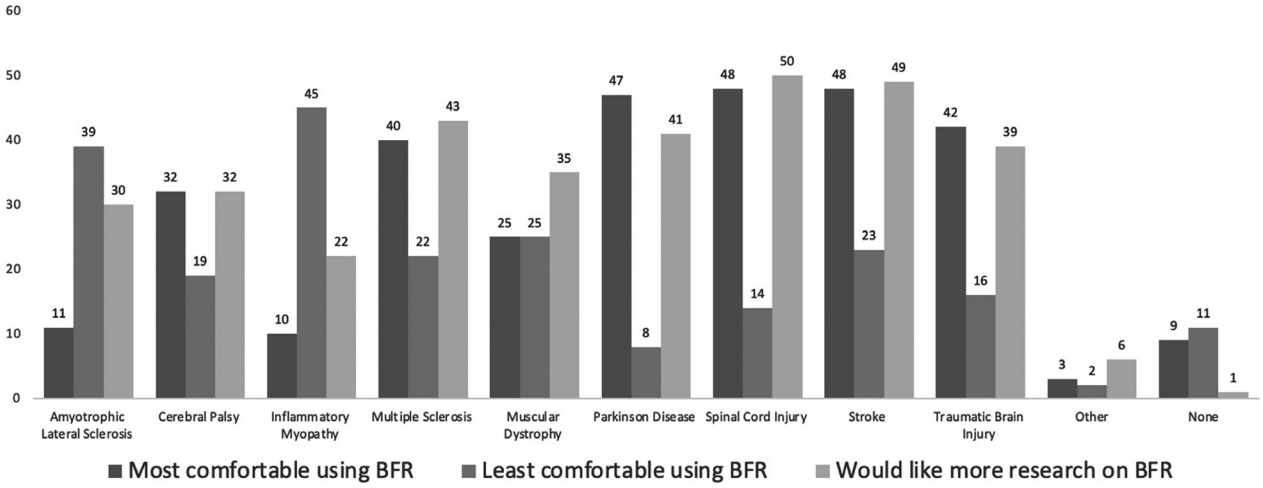

Fig. 4. Frequency of reported comfort level and research needs (assuming access to people with neurologic conditions).

in these populations. The current study also found that BFR was most often applied during resistance and aerobic training, which is consistent with the evidence from people with musculoskeletal conditions[2, 3] and older adults[25]. The majority of survey respondents also reported using BFR in people who were walking independently or with a unilateral assistive device. While much of the literature on BFR in people with neurologic conditions has also focused resistance training in people who are ambulatory[12, 13, 18–21], people who have more severe mobility restrictions might benefit most from BFR as they may be less likely to tolerate higher intensities or loads[25]. Therefore, while additional research on resistance training with BFR in a variety of neurologic conditions is needed, it may be particularly useful to study BFR in people with stroke and TBI, and in those with more severe mobility limitations.

Historically, there have been concerns regarding the safety of BFR due to the potential of serious side-effects (e.g., venous thromboembolism, rhabdomyolysis, etc.). However, a survey conducted by Nakajima et al.[26] reported that out of almost 13,000 adults without neurologic conditions (up to age 80) these serious side-effects following exercise with BFR were extremely rare (0.008–0.055%). While the current study had a relatively small sample and was subject to potential recall bias, no serious side-effects requiring medical attention were reported, and side-effects causing the treatment to stop were rare. The most common side-effect reported during BFR intervention was intolerance to cuff pressure, which resulted in some clinicians deciding to cease treatment altogether (serious side-effect), while others reported adjusting pressure and continuing treatment (minor side-effect). Based on the current literature in musculoskeletal conditions, LOPs up to 80% of maximal LOP are recommended to optimize strength and hypertrophy gains[2], however, it could be that clinicians were concerned that higher LOPs could harm patients. Therefore, in order to inform clinical decisions regarding application and cessation in people with neurologic conditions, more research is needed to determine optimal cuff pressures, and to thoroughly investigate safety, feasibility, and tolerance.

While survey respondents in this study reported a variety of benefits associated with BFR training for their patients with neurologic conditions, these retrospectively reported clinical observations do not formally support the efficacy of BFR use in these conditions[27]. The most common benefit was improved muscle strength, which is consistent with the BFR literature in people with musculoskeletal conditions and older adults[3]. There is also early evidence to support improved or maintained strength following BFR training in people with CP[12], MS[19], PD[21], SCI[23], and inclusion body myositis[13]. The next most commonly reported benefit of BFR was decreased fatigue. Of note, two studies on BFR use in people with MS have reported a modest decrease in fatigue perception[18, 19]. In contrast, a BFR study in people with inclusion body myositis reported 2/11 participants in the BFR group left the study due to severe fatigue[13]. It would be expected that BFR, like any progressively dosed exercise, might temporarily cause performance-related fatigue (and indeed fatigue was also commonly reported as a side effect of BFR in this survey). However, given the high prevalence of fatigue in people with neurologic conditions[28], more study is needed to determine the efficacy of BFR on performance fatigue and/or fatigue perception outcomes. Finally, survey respondents also commonly reported improved pain following BFR use. A recent review concluded that exercise with BFR may be an effective pain management strategy for people with musculoskeletal conditions[29]. Pain is also common in neurologic conditions[30], and two feasibility trials of BFR in people with MS and SCI have both shown that resistance training with BFR at least does not increase pain or delayed onset muscle soreness compared to training without BFR[20, 22]. Altogether, efficacy research is needed for exercise with BFR in people with neurologic conditions, and the results of this survey suggest that outcomes of strength, fatigue, and pain may be especially important to consider.

This survey asked questions about clinical decision-making based on the use of evidence, clinical judgment, and patient input[31]. Interestingly, while there is a clear paucity of evidence for BFR use in people with neurologic conditions, many respondents reported using evidence to support their decision to use BFR. However, many also relied on their clinical judgment, commonly opting to use BFR when other treatments were not successful, and opting not to use BFR when other treatments were already working. This decision, while seemingly obvious, may highlight an important consideration when selecting interventions for patients with neurologic conditions: newer modalities like BFR may be helpful in certain scenarios, particularly when standard treatments aren't as effective. Finally, respondents indicated they most often introduced the idea of BFR to their patients, although some respondents reported that their patients initiated the discussion. Therefore, while BFR continues to grow in popularity, it is important to have evidence supporting if and when it could be helpful for people with neurologic conditions.

The construct of "people with neurologic conditions" is heterogeneous, and it was clear that survey respondents were more comfortable with BFR use in some conditions over others. For example, very few reported being comfortable using BFR in people with ALS, which could possibly be because relatively little is known about progressive training in ALS[32]. Additionally, despite several studies examining safety and feasibility of BFR in people with inflammatory myopathies[13–17], very few survey respondents were comfortable using BFR in these conditions, possibly because they are relatively rare and not commonly seen by clinicians. In contrast, in neurologic conditions where there is ample research on exercise (e.g., stroke, MS, PD, SCI)[10, 33], many respondents reported they would be comfortable applying BFR. Finally, despite most respondents being willing to use BFR in at least some neurologic conditions, it was clear from this survey that additional research and training is needed across a variety of conditions.

This study was limited by the relatively small sample size. In addition, based on the use of snowball sampling, it was not possible to know the overall response rate in this study. Not every respondent completed the survey, although there were no differences in the characteristics of the completers and non-completers. This study also included mostly physical therapists

who all practice in the United States, and who mostly identified as male and Caucasian. Therefore, these results may have limited generalizability to a wider range of clinicians.

The results of this study provide novel, preliminary data suggesting that practitioner use of BFR in people with neurologic conditions is somewhat common in spite of a relative paucity of evidence on its safety, feasibility, and efficacy. Although this study could have been limited by recall bias and lack of objective outcome data, practitioners perceived BFR to be safe and beneficial for patients with neurologic conditions. More evidence and training, however, is needed to support future clinical use and the results from this survey may help to inform future research priorities.

Conference presentation

Some data from this manuscript were accepted for a poster presentation at the 2022 American Physical Therapy Association Combined Sections Meeting.

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