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ORIGINAL ARTICLE

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Body image and perception among adults with and without phantom limb pain

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Abstract

Background: Following lower-limb amputation, phantom limb pain (i.e., pain perceived as coming from the amputated portion of the limb) is common. Phantom limb pain may be associated with impaired body image and perception, which may be targets for rehabilitative intervention.

Objective: To compare measures of body image and perception between adults with and without phantom limb pain post amputation and evaluate associations between measures of body image and perception and phantom limb pain.

Design: Survey.

Setting: Online, remote assessment.

Participants: Seventy-two adults ≥1 year post unilateral lower-limb loss ($n = 42$ with phantom limb pain, $n = 30$ without phantom limb pain or pain in the remaining portion of the limb).

Interventions: Not applicable.

Main Outcome Measures: Self-reported outcome measures assessing body image (i.e., Amputee Body Image Scale-Revised), perceptual disturbances associated with the phantom limb (i.e., a modified Bath Complex Regional Pain Syndrome Body Perception Disturbance Scale), and prosthesis satisfaction (i.e., Trinity Amputation and Prosthesis Experience Scale) were administered; participants with phantom limb pain reported pain interference via the Brief Pain Inventory-Short Form. Between-group comparisons of self-reported outcome measure scores were conducted using Mann Whitney U or chi-square tests, as appropriate ($a = .05$).

Results: Compared to peers without phantom limb pain, adults with phantom limb pain reported more negative body image; increased phantom limb ownership, attention, and awareness; and reduced prosthesis satisfaction and embodiment ($U = 175.50$–364.00, $p < .001$ to $.034$). Disturbances in phantom limb perception (i.e., size, weight, pressure, temperature) were similar between groups ($p = .086$ to $>.999$). More negative body image was associated with increased phantom limb pain interference ($\tau_b = .25$, $p = .026$).

Conclusions: Adults with phantom limb pain demonstrate more negative body image and hypervigilance of the phantom limb as compared to peers with non-painful phantom sensations. Mind-body treatments that target impaired body image and perception may be critical interventions for adults with phantom limb pain.

INTRODUCTION

Lower-limb loss (LLL), that is, amputation of the lower extremity, may detrimentally affect bodily perception and experience. Following LLL, individuals must adapt to their new body physically (e.g., learning to use a prosthesis) and emotionally (e.g., learning to view and accept their amputated limb).[1] Consequently, many adults with LLL report body and prosthesis dissatisfaction, which is associated with more severe depressive symptoms and worse quality of life.[2-5]

Beyond acclimating to physical changes post LLL, many adults must also adapt to phantom limb sensations, that is, sensations perceived as coming from the amputated portion of the limb.[6] Although phantom limb sensations can be nonpainful, phantom limb pain (PLP) affects up to 80% of adults post LLL[7] and presents as symptoms of burning, throbbing, or electric shocks.[8] Furthermore, painful phantom limbs can feel retracted into proximal regions of the limb (i.e., telescoped) or stuck in awkward, uncomfortable positions.[8,9]

PLP may reflect underlying disruptions in the brain's representation of the amputated limb due to mismatching sensory and motor feedback.[10] Upper-extremity PLP has been associated with somatosensory cortex reorganization[11-13]; greater shifts in the limb's somatosensory representation have been associated with greater pain intensity and telescoping.[14] Although changes in implicit, somatosensory representation have received attention among individuals with PLP, changes in explicit body representation (i.e., conscious body image and perception) remain understudied.

As several cortical areas (e.g., somatosensory, prefrontal, and anterior cingulate cortices, amygdala) have shared roles in both pain perception and body representation,[15] impaired body image and perception may be modifiable factors to target among adults with PLP. Imagery-based treatment techniques aiming to improve body image and perception have shown promise in reducing pain intensity among adults with PLP and other pain conditions involving distorted body perceptions, for example, Complex Regional Pain Syndrome (CRPS).[16,17] Additional research, however, is needed to determine whether similar perceptual disturbances (e.g., disownership, as is frequently present in CRPS) are observed in PLP, and whether impaired body image and perception are associated with pain-related outcomes post LLL.

Sündermann et al. published a theoretical model linking body image, body perception, and chronic pain, suggesting negative body image and distorted body perception may perpetuate negative body-related attitudes and reinforce unfavorable pain behaviors.[18] Building upon this model, we hypothesized potential intersections of body image, body perception, and PLP (Figure 1). PLP may co-occur with distorted body perceptions (e.g., disownership), which may generate adverse, pain-related emotions, drawing focused attention to the limb. Hypervigilant attention to and awareness of the phantom limb may facilitate impaired pain processing, including maladaptive coping strategies or adverse pain cognitions (e.g., pain catastrophizing) that exacerbate the PLP cycle.

To provide preliminary evidence of these proposed relationships, this study investigated whether adults with PLP demonstrate impaired body image and perception

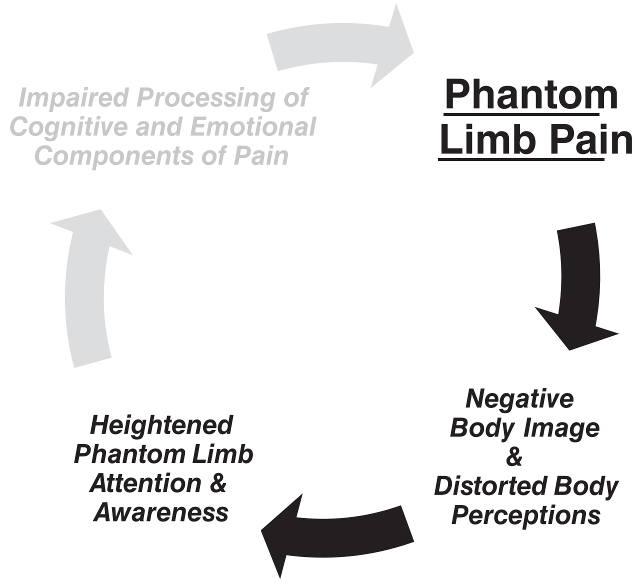

FIGURE 1 A proposed model depicting the cyclic relationship between phantom limb pain (PLP) and body image and perception. To provide support to underlying relationships among PLP, body image, and body perception proposed in this preliminary model, this study investigated whether PLP characteristics (i.e., pain intensity, pain interference) are associated with negative body image and distorted body perceptions, including phantom limb hypervigilance (denoted in black). If present, these associations may lay critical groundwork for future studies investigating further relationships between body image and perception and impaired pain processing (in grey), including cognitive pain responses (e.g., pain catastrophizing and other pain-related thought patterns) and emotions (e.g., sadness, shame, stress)

as compared to peers without PLP and sought to determine whether body image and perception are associated with PLP characteristics. We hypothesized adults with PLP would demonstrate (1) more negative body image, (2) increased phantom limb attention and awareness, and (3) disturbances in perceived phantom limb characteristics (e.g., disownership, altered sensations). Secondarily, we hypothesized more negative body image and increased phantom limb attention and awareness would be associated with worse pain characteristics.

METHODS

Participants were recruited between August 2020 and March 2021 for this online survey study, through advertisements and consent-to-recontact databases in the Delaware Limb Loss Studies laboratory and local prosthetic clinics. This study was approved by the University of Delaware Institutional Review Board for Human Subjects Research.

Adults (aged 18–75 years) ≥1 year post unilateral LLL were recruited if they were English speaking and reading, had access to a computer and reliable internet service, and demonstrated basic computer skills (i.e., keyboard typing, independent internet use). As prosthesis use may be associated with body image,[19] adults were excluded if they did not use a prosthesis. Furthermore, as this study was part of a larger project investigating body representation following acquired LLL, adults with congenital limb deficiency or who had participated in treatment targeting body representation (e.g., graded motor imagery,[16] mirror therapy[20]) were excluded.

During screening, adults reported whether they experienced PLP, as well as residual limb pain (i.e., pain in the remaining portion of the affected limb, RLP). Participants who reported PLP (with or without RLP) within the past month were classified into the PLP group, and participants who denied PLP or RLP were classified into the No PLP group. Because of this study's focus on PLP, participants reporting RLP only (without the presence of PLP) were excluded.

After electronically signing informed consent forms, enrolled participants completed data collections remotely via Gorilla, a fee-for-service platform hosted on Microsoft Azure.[21] For characterization purposes, participants provided demographic and amputation-related information via standardized questionnaires and reported depressive symptoms via the Patient Health Questionnaire-9 (PHQ-9).[22] Reliability and validity of the PHQ-9 have been reported; scores ≥10 are highly sensitive and specific for major depression.[22]

Prosthesis-related measures

Participants completed the Houghton Scale[23] and Socket Comfort Score,[24] assessments of prosthesis use and stability when ambulating with a prosthesis and prosthetic socket comfort, respectively. The Houghton Scale score ranges from 0–12 points, where greater scores indicate greater prosthesis use and perceived stability when ambulating with a prosthesis.[23] The Socket Comfort Score is an 11-point scale assessing prosthetic socket comfort (0 = "most uncomfortable socket fit" to 10 = "most comfortable fit imaginable"); best and worst scores in the past 24 hours were averaged for analyses. Reliability and validity of the Houghton Scale and Socket Comfort Score have been reported.[24,25]

Participants reported their duration of prosthesis experience and rated their prosthesis embodiment on a 3-point Likert scale (i.e., 0 = "my prosthesis feels like a tool to help me walk but does not feel like it belongs to me," 1 = "my prosthesis feels somewhat like my amputated leg," 2 = "my prosthesis feels like it is my amputated leg and belongs to me"). Participants also completed subscales of the Trinity Amputation and Prosthesis Experience Scales-Revised (TAPES-R).[26] The Aesthetic Satisfaction subscale is a 3-item assessment of satisfaction with prosthesis color, shape, and appearance; scores range from 3 to 9 points. The Functional Satisfaction subscale is a 5-item assessment of satisfaction with prosthesis weight, usefulness, reliability, fit, and comfort; scores range from 5 to 15 points. For both subscales, higher scores indicate greater satisfaction.[26]

Phantom and residual limb characteristics

Across both groups, participants with any phantom sensations (including nonpainful sensations and/or PLP) completed outcome measures assessing phantom limb characteristics. The Limb Deficiency and PLP Questionnaire[27] assessed phantom limb characteristics (e.g., sensation type, duration, frequency), as applicable. Using a Bothersomeness Scale, participants rated how bothered they were by phantom and residual limb phenomena (as applicable) on separate, 3-point scales (0 = "not bothered at all" to 3 = "extremely bothered").[28]

Among adults in the PLP group only, best and worst PLP and RLP intensity in the past 24 hours were captured using a numeric pain rating scale (i.e., 0 = no pain, 10 = worst pain imaginable[29]); scores were averaged for analyses. Furthermore, PLP interference was evaluated using the Brief Pain Inventory-Short Form (BPI-SF) Pain Interference domain.[30] Participants rated PLP interference over the past week (0 = "does not interfere" to 10 = "completely interferes") across seven domains: general activity, mood, walking ability, normal work, relations with other people, sleep, and enjoyment of life.[31] Reliability and validity of the BPI-SF Pain Interference domain have been reported among patients with osteoarthritis, multiple sclerosis, and spinal cord injury.[32-34]

Body image and perception

Finally, participants completed the Amputee Body Image Scale-Revised (ABIS-R[35]) and a modified version of the Bath CRPS Body Perception Disturbance Scale.[36] The ABIS-R is a 14-item assessment of attitudes toward the body with reported reliability and validity.[35] Twelve of the items are scored from 0 ("none of the time") to 2 ("most/all of the time"), whereas two are reverse scored. The sum of items produces a total score (maximum: 28 points); higher scores indicate more negative body image.[35]

The Bath, which was originally created for adults with CRPS,[36] asked participants to rate their phantom limb perception with respect to the following domains: ownership, awareness, attention, and emotional feelings.[36] Additionally, dichotomous (Yes/No) questions were used to ascertain perceptual differences in phantom limb size, temperature, pressure, and weight, as compared to the intact limb. If differences were perceived, participants were asked to elaborate using text

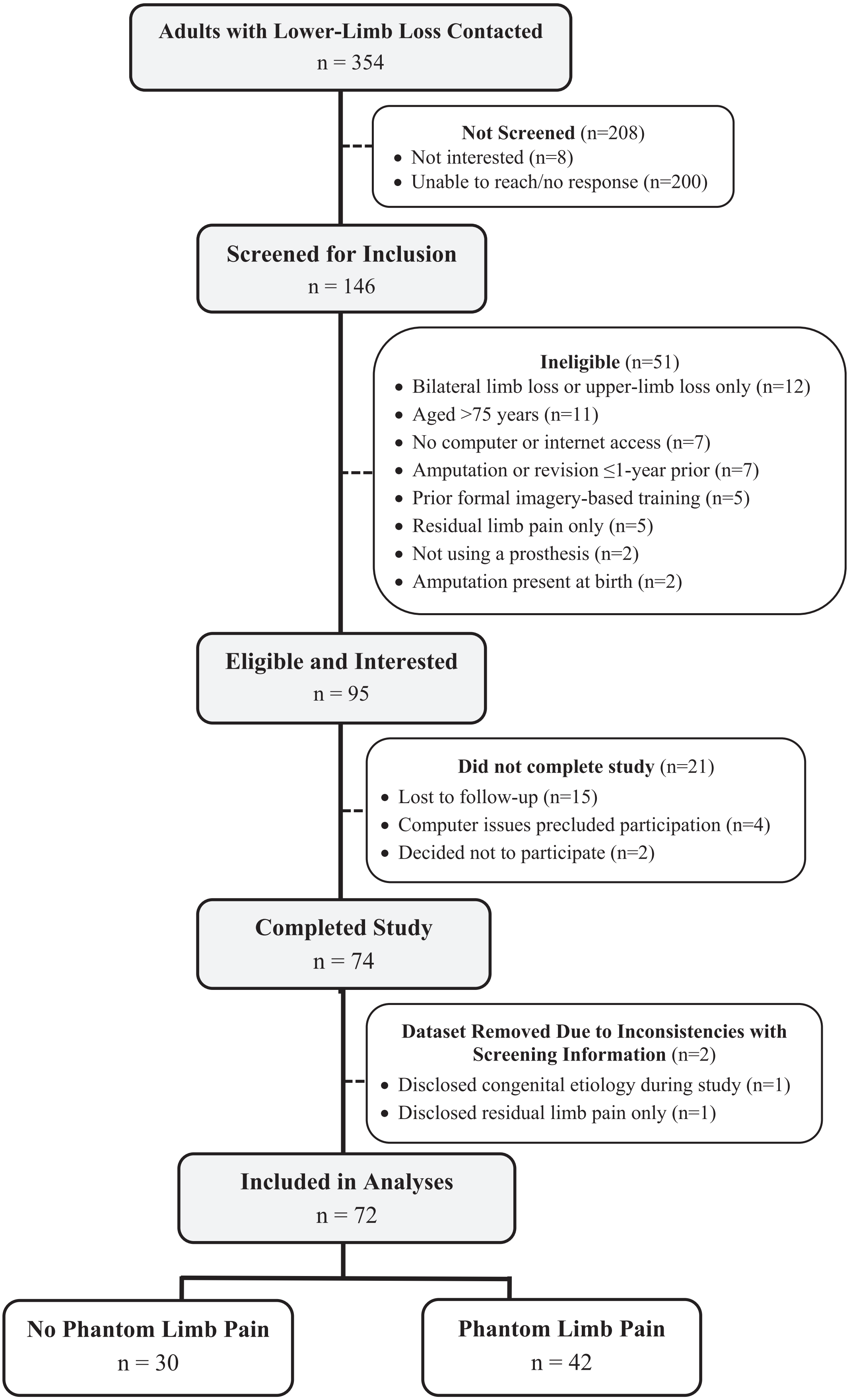

FIGURE 2 Participant inclusion

TABLE 1 Participant characteristics

Variable	No phantom limb pain (n = 30)	Phantom limb pain (n = 42)	*p*
Demographics			
Sex, female[a]	12 (40%)	19 (45%)	.658
Race[a]			
White or Caucasian	27 (91%)	40 (95%)	.401
Black or African-American	1 (3%)	2 (5%)	
Asian	1 (3%)	0 (0%)	
More than 1 race	1 (3%)	0 (0%)	
Ethnicity[a]			
Non-Hispanic	29 (97%)	41 (98%)	>.999
Hispanic	1 (3%)	1 (2%)	
Age, years[b]	55 (13)	54 (13)	.750
Height, cm[b]	172.4 (10.1)	171.5 (11.8)	.743
Weight with prosthesis, kg[b]	88.8 (22.8)	88.0 (21.2)	.876
Amputation-related details			
Amputation type[a]			
Transtibial	20 (67%)	22 (53%)	.247
Transfemoral	7 (23%)	18 (43%)	
Knee disarticulation	2 (7%)	1 (2%)	
Hip disarticulation	0 (0%)	1 (2%)	
Rotationplasty	1 (4%)	0 (0%)	
Amputation reason[a]			
Trauma	10 (33%)	18 (43%)	.298
Cancer	5 (17%)	9 (21%)	
Infection	4 (13%)	8 (19%)	
Dysvascular	5 (17%)	5 (12%)	
Multiple or other reasons	6 (20%)	2 (5%)	
Time since amputation, years[c]	9 (3, 26)	9 (4, 20)	.744
Prosthesis-related details			
Prosthesis experience[a]			
6 months-1 year	1 (3%)	0 (0%)	.592
1–3 years	1 (3%)	1 (2%)	
3–5 years	11 (37%)	13 (31%)	
>5 years	17 (57%)	28 (67%)	
TAPES-R Satisfaction with prosthesis subscales[c]			
Aesthetic satisfaction, 3–9 points	8 (6, 9)	6 (6, 8)	.100
Functional satisfaction, 5–15 points	14 (10, 15)	10 (9, 12)	**<.001**
Houghton scale, 0–12[c]	12 (11, 12)	10 (9, 12)	**.003**
Average socket comfort score, 0–10[b,d]	n = 29	n = 40	**<.001**
	8.3 (1.2)	6.5 (1.6)	
Depressive symptoms			
PHQ-9 total score, 0–27[c]	n = 29	n = 40	**.024**
	2 (0, 4)	4 (1, 7)	
PHQ-9 total score ≥ 10[a,e]	n = 29	n = 40	.073
	1 (3%)	8 (19%)	

Note: Significant between-group differences are bolded.
Abbreviations: PHQ-9, Patient Health Questionnaire–9; TAPES-R, Trinity Amputation and Prosthesis Experiences Scale - Revised.
[a]Data presented as n (% of sample).
[b]Data presented as mean (SD).
[c]Data presented as median (25th, 75th percentile).
[d]Two participants (one in the No Phantom Limb Pain group and one in the Phantom Limb Pain group) reported having osseointegrated prostheses; therefore, they did not complete the Socket Comfort Score. One additional participant in the pain group left their Socket Comfort Scores blank.
[e]Scores ≥ 10 on the Patient Health Questionnaire–9 are highly sensitive and specific for major depression.

TABLE 2 Characteristics of phantom limb sensations and pain

Variable	No phantom limb pain (n = 30)	Phantom limb pain (n = 42)	*p*
Phantom limb sensations			
Nonpainful sensations present[a]	21 (71%)	37 (88%)	.056
Bothersomeness[a]	n = 21	n = 37	
Not bothered	18 (86%)	24 (65%)	.215
Somewhat bothered	3 (14%)	12 (32%)	
Extremely bothered	0 (0%)	1 (3%)	
Phantom limb pain			
Average intensity in past 24 h, 0–10[b]	-	2 (2, 5)	-
Bothersomeness[a]			
Not bothered	-	8 (19%)	-
Somewhat bothered	-	31 (74%)	
Extremely bothered	-	3 (7%)	
Frequency of pain in past week[a]			
Never	-	4 (10%)	-
1–3 times per week	-	17 (41%)	
4–6 times per week	-	8 (19%)	
Once per day	-	3 (7%)	
Multiple times per day	-	9 (21%)	
Constant pain	-	1 (2%)	
Duration of pain in past week[a]		n = 41	
<1 min	-	12 (29%)	-
Several minutes but < 1 h	-	19 (46%)	
Several hours	-	6 (15%)	
Several days	-	4 (10%)	
BPI-SF pain interference domain, 0–10[b]	-	1.29 (0.43, 2.86)	-
Residual limb pain			
Residual limb pain present[a]	-	28 (67%)	-
Average intensity in past 24 h, 0–10[b]	-	n = 28 3 (2, 5)	-
Bothersomeness[a]		n = 28	
Not bothered	-	10 (36%)	-
Somewhat bothered	-	16 (57%)	
Extremely bothered	-	2 (7%)	

Abbreviation: BPI-SF, Brief Pain Inventory-Short Form.
[a]Data presented as n (% of sample).
[b]Data presented as median (25th, 75th percentile).

entry. Participants in the No PLP group without phantom limb phenomena (n = 9) did not complete the Bath.

Statistical analyses

Using SPSS Version 26 (IBM Corp., Armonk, NY, USA), participant characteristics were evaluated using descriptive statistics. ABIS-R and Bath subscale scores were compared between groups using Mann Whitney U tests, as data did not meet parametric assumptions (Shapiro-Wilk tests: $p < .050$). Using chi-square tests (or Fisher's exact test, if expected observations per category were < 5), between-group differences in phantom limb perceptual disturbances (per the Bath) were evaluated ($\alpha = .050$).

For adults in the PLP group, Kendall's tau-beta correlation coefficients (τ_b) were calculated among measures of body image, body perception, and PLP ($\alpha = .050$), given their nonparametric distributions. τ_b coefficients have been shown to have better statistical properties for evaluating associations between ordinal and nonparametric outcomes as compared to Spearman's correlation coefficients.[37] Values may be considered as follows: ≤.07 = negligible, .08–26 = weak, .27–48 = moderate, .49–71 = strong, ≥.72 = very strong.[38] A post-hoc Benjamini-Hochberg correction was applied to control for multiple comparisons (false discovery rate = .1).[39]

TABLE 3 Differences in body image, body perception, and prosthesis embodiment between adults with and without phantom limb pain

Variable	No phantom limb pain[a] (n = 30)	Phantom limb pain (n = 42)	p
Body image			
ABIS-R, 0–28 points[b] Higher scores = more negative body image	n = 29 4 (1, 8)	n = 42 7 (5, 12)	**.004**
Body perception			
Bath: phantom limb ownership, 0–10[b] 0 = Very much a part, 10 = Completely detached	n = 21 4.0 (1.0, 8.0)	n = 42 2.0 (0.0, 4.0)	**.034**
Bath: phantom limb awareness, 0–10[b] 0 = Very aware, 10 = Completely unaware	n = 20 6.5 (1.3, 9.8)	n = 42 1.0 (0.0, 5.0)	**.013**
Bath: phantom limb attention, 0–10[b] 0 = Full attention, 10 = No attention	n = 21 9.0 (8.0, 10.0)	n = 42 5.0 (2.8, 9.0)	**<.001**
Bath: emotional feelings about the phantom limb, 0–10[b] 0 = Strongly positive, 10 = Strongly negative	n = 21 5.0 (0.0, 5.0)	n = 42 5.0 (1.0, 7.0)	.173
Bath: phantom limb disturbances[c]	n = *22*	n = *42*	
Size	0 (0%)	6 (14%)	.086
Temperature	3 (14%)	9 (21%)	.521
Pressure	4 (18%)	11 (26%)	.473
Weight	2 (9%)	5 (12%)	>.999
Prosthesis embodiment[c]			
Not embodied "My prosthesis feels like a tool to help me walk but it does not feel like it belongs to me."	7 (23%)	23 (55%)	**.028**
Somewhat embodied "My prosthesis feels somewhat like my amputated leg."	8 (27%)	6 (14%)	
Embodied "My prosthesis feels like it is my amputated leg and it belongs to me."	15 (50%)	13 (31%)	

Note: Significant between-group differences are bolded.
Abbreviations: ABIS-R, Amputation Body Image Scale–Revised; Bath, Bath CRPS Body Perception Disturbance Scale.
[a]Nine participants in the No Phantom Limb Pain group reported no presence of a phantom limb; therefore, they did not complete the Bath Body Perception Disturbance Scale.
[b]Data presented as median (25th, 75th percentile).
[c]Data presented as n (% of sample).

RESULTS

Of the 354 individuals contacted for this study, 146 underwent eligibility screening (see Figure 2), and 95 eligible individuals were provided electronic informed consent forms. Of the 74 participants who completed the study, two disclosed criteria during study completion rendering them ineligible; therefore, 72 participants (n = 42 in the PLP group, n = 30 in the No PLP group) were analyzed.

Participant characteristics

Demographics between groups were similar ($p = .401$ to >.999; see Table 1). Regardless of group, participants reported predominantly traumatic, transtibial amputations, and median time since LLL was 9 years. PHQ-9 scores indicated the PLP group reported greater depressive symptoms than pain-free peers ($U = 418.00$, $p = .024$), but the prevalence of major depression was similar between groups ($p = .073$).

Prosthesis experience was similar between groups, with most participants reporting >5 years of prosthesis use. Participants in the PLP group, however, reported lower Houghton Scale ($U = 376.00$, $p = .003$) and Socket Comfort Scores ($t = 5.11$, $p < .001$), indicating reduced prosthesis use, perceived prosthetic stability, and socket comfort among adults with PLP. Finally, functional prosthesis satisfaction was significantly higher among adults in the No PLP group ($U = 314.50$, $p < .001$), whereas aesthetic prosthesis satisfaction was similar between groups ($p = .100$).

Across groups, most participants reported nonpainful phantom limb sensations that were not bothersome (see

Disturbance	No Phantom Limb Pain	Phantom Limb Pain
Phantom Limb Size	--	*"Much larger - swollen."* *"Non-amputated [leg] looks and feels 'normal'; phantom limb, when present, is always tingling."*
Phantom Limb Temperature	*"[My phantom limb] feels warm or cold based on my socket, not based on the non-amputated side."* *"Usually no [differences], but if anything, it will feel a little colder. Another weird phantom thing - walking in wet grass wearing sandles, my phantom foot will feel cold and wet, sometimes a bit sooner than my flesh and bone foot. Similar with AC on in the car and blowing on my legs."* *"It gets colder easier."* --	*"Hot or burning."* *"I feel burning."* *"My limb recalls the last sensation it felt, that is an IED explosion. I feel heat, pressure, excruciating pain, electric shocks running to what I imagine is a sympathetic nerve in my left gut and then running back to my leg and then back to the gut in wave after wave after wave."* *"[My phantom limb] often feels more cold - even if I use blankets and such to try and warm my stump."*
Phantom Limb Pressure	*"I sometimes feel like the foot of the amputated lower leg is being squeezed laterally."* *"Phantom feels contained as in cam-walker boot when sitting still, sometimes too snug but that goes away if I move it."* --	*"I feel the pressure of the [IED] blast."* *"I often feel pressure and nerve pain after being on my feet for a long period of time."* *"It always feels tight."* *"I have one spot that I feel like the pain is coming from, there is pressure there."*
Phantom Limb Weight	*"Lighter."* *"Lighter than my other leg."* --	*"[My phantom limb] often seems short but heavy."* *"Feels heavy, probably because of prosthetic."* *"[My phantom limb] often feels more heavy than my sound side."*

FIGURE 3 Examples of phantom limb perceptual disturbances among adults with and without phantom limb pain. IED, improvised explosive device

Table 2). Most participants in the PLP group (i.e., 81%) reported their PLP was at least "somewhat bothersome" (average intensity: 2/10). Participants largely reported PLP at a frequency of "multiple times per week" and duration of "several minutes (but <1 h)." Despite self-reported bothersomeness, frequency, and duration of PLP, PLP interference was low (median BPI-SF Pain Interference score: 1.29). Finally, 67% of the PLP group reported RLP (average intensity: 3/10), which was largely classified as "somewhat bothersome."

Body image and perception

ABIS-R scores were higher among the PLP group compared to the No PLP group ($U = 364.00$, $p = .004$; see Table 3), indicating more negative body image perception. Bath subscale scores indicated greater phantom limb ownership, awareness, and attention among adults in the PLP group compared to No PLP peers ($U = 175.50$–297.00, $p < .001$ to $.034$); however, emotions toward the phantom limb were similar between groups ($p = .173$).

Disturbances in phantom limb perception, as assessed by the Bath, were relatively rare, and proportions of disturbances were similar between groups ($p = .086$ to $>.999$). Disturbances in phantom limb pressure were most prevalent, with 4 participants (18%) in the No PLP group and 11 participants (26%) in the PLP group reporting perceived pressure differences. Despite similarities in the prevalence of phantom limb disturbances, text entries describing phantom limb characteristics differed between groups (see Figure 3). Specifically, participants in the PLP group commonly

TABLE 4 Correlations among body image, body perception, and phantom limb pain (n = 42)

	ABIS-R	Bath - Ownership	Bath - Awareness	Bath - Attention	Bath - Emotional feelings	BPI-SF average pain interference	Average phantom limb pain intensity
ABIS-R	1						
Higher scores = More negative body image							
Bath – Ownership	.10 (.410)	1					
0 = Very much a part, 10 = Completely detached							
Bath– Awareness	−.04 (.746)	**.40 (.001)**	1				
0 = Very aware, 10 = Completely unaware							
Bath– Attention	.17 (.150)	.12 (.309)	**.30 (.012)**	1			
0 = Full attention, 10 = No attention							
Bath– Emotional Feelings	**.39 (.001)**	.124 (.309)	.07 (.570)	.15 (.198)	1		
0 = Strongly positive, 10 = Strongly negative							
BPI-SF average pain interference	**.25 (.026)**	.05 (.650)	.02 (.841)	.02 (.844)	**.26 (.023)**	1	
Average phantom limb pain intensity	−.03 (.792)	−.05 (.680)	−.02 (.902)	−.25 (.034)	.09 (.428)	**.44 (<.001)**	1

Note: Data presented as Kendall's tau (*p* value), with significant associations (after Benjamini-Hochberg corrections) bolded.
Abbreviations: ABIS-R, Amputee Body Image Scale-Revised; Bath, Bath CRPS Body Perception Disturbance Scale; BPI-SF, Brief Pain Inventory-Short Form.

reported disturbances associated with discomfort (e.g., "swollen," "burning," "pressure of the IED [improvised explosive device] blast"), whereas the No PLP group perceived the phantom limb as "lighter" than the intact limb or associated with environmental changes in temperature. Furthermore, self-reported prosthesis embodiment differed between groups, with most adults in the PLP group perceiving their prosthesis as a tool, whereas pain-free adults largely perceived their prosthesis as part of their body ($p = .028$).

Relationships among body perception and pain

Positive correlations were found among BPI-SF Pain Interference Domain, ABIS-R, and Bath Emotional Feelings scores ($\tau_b = .25–39$, $p = .001$ to .026; see Table 4), indicating associations among higher PLP interference and more negative body image and emotions. PLP intensity was negatively correlated to Bath Attention scores ($\tau_b = -.25$, $p = .034$), indicating higher pain intensity was associated with greater phantom limb attention (i.e., a lower Bath Attention score); however, this association was nonsignificant after correcting for multiple comparisons.

DISCUSSION

Although PLP is thought to reflect significant changes in body representation, this is among the first studies to directly compare body image and perception between adults with and without PLP. Findings supported our hypotheses of more negative body image and increased phantom limb attention and awareness among adults with PLP as compared to pain-free peers, indicating these may be key areas to target in rehabilitation. Furthermore, as hypothesized, greater PLP interference was associated with more negative body image and emotions toward the phantom limb, indicating a potential area for evaluation and intervention. In contrast, our remaining hypotheses (i.e., significant perceptual disturbances among adults with PLP, associations between phantom limb attention and PLP characteristics) were not supported.

Selective attention to pain generators is associated with negative pain cognitions (e.g., pain catastrophizing) and adverse behaviors in response to pain (e.g., avoidance of pain-inducing activities).[40] In contrast, distraction techniques may increase descending pain modulation, significantly reducing pain perception.[41] In this study, adults with PLP demonstrated greater phantom limb attention and awareness as compared to pain-free peers. Notably, increased phantom limb attention was also associated with higher pain intensity; however, relationships between attention and pain intensity were not statistically significant after accounting for multiple comparisons ($p = .034$). Findings provide preliminary support to the proposed model (Figure 1) adopted from Sündermann et al.,[18] suggesting phantom limb attention is heightened with PLP. Future studies may consider investigating the remaining pathways of this model (i.e., associations between increased attention and pain processing in PLP) as well as explore other mediating and moderating factors that may contribute to these relationships.

In CRPS, patients commonly report disownership and negative perceptual disturbances (e.g., swelling) of the painful body part.[36,42] Although the physiological contributions to painful body part disownership and perceptual disturbances are debated,[43,44] these impairments may be, in part, attributed to shrinkage in the somatosensory representation of the painful body part.[10] Given evidence of somatosensory reorganization following upper-limb loss,[11] we hypothesized adults with PLP may demonstrate similarly-distorted phantom limb imagery (e.g., disownership, perceptual disturbances in phantom limb characteristics); however, this hypothesis was not fully supported. In this study, adults with PLP largely reported phantom limb ownership (attachment) and similar frequencies of perceptual disturbances as compared to peers without PLP. As Bath Ownership scores were correlated to Bath Awareness scores, increased phantom limb attachment may be explained by increased phantom limb awareness and perception.

Interestingly, the PLP group more frequently reported perception of the prosthesis as a tool rather than part of the body, indicating potentially reduced embodiment of the prosthesis with PLP. As prosthesis use activates the same cortical areas as limb movement[45] and is represented in the same region of the somatosensory cortex as the phantom limb,[46,47] it is possible that prosthesis embodiment is limited when the painful phantom limb is perceived as fully attached. Following upper-limb loss, prior studies have reported convergence between the phantom limb and prosthesis, which may help enable prosthetic control and acceptance[47]; however, this study suggests the painful phantom limb may interfere with successful prosthesis integration into one's body representation and image. Consequently, future studies may consider investigating whether addressing PLP improves prosthesis embodiment, satisfaction, and use.

Although the prevalence of phantom limb disturbances was similar between groups, potential evidence of altered central pain processing is indicated by differences in subjective, qualitative PLP characteristics. For example, individuals with PLP commonly used unpleasant descriptors (e.g., burning, swollen, heavy), whereas pain-free participants used neutral descriptors (e.g., lighter, colder) and reported resolution with movement or environmental changes. Findings augment prior qualitative work describing perceptual disturbances reported with phantom limb phenomena[8] by directly comparing qualitative descriptors between those with and without pain.

Similarly, although both groups reported largely neutral feelings toward their limb (median score = 5), associations were observed between emotions toward the phantom limb and PLP interference. Thus, although the presence of PLP alone may not differentiate between those with negative versus positive phantom limb perceptions, emotional acceptance of the painful phantom limb may contribute to the degree of pain interference in daily experiences (e.g., mood, enjoyment of life).

Most participants in this study experienced traumatic or cancer-related LLL, which may have unique implications with respect to body image and perception given both cancer and traumatic physical injuries are associated with negative body image[48-50] and distorted body perception.[51,52] Regardless of etiology, however, all acquired amputations result in a significant change in body structure and experience,[1] which may similarly affect body image and perception. Although comparisons of body image and perception across various amputation etiologies are outside the scope of this study, future studies may consider evaluating whether amputation etiology uniquely affects one's bodily experience post LLL.

Recently, body image dissatisfaction was identified as a critical factor to assess following amputation,[53] as body image has been shown to independently predict psychosocial outcomes (e.g., depressive symptoms, anxiety) above and beyond demographic characteristics and comorbid medical conditions.[5] Our findings support initiatives to evaluate body image post LLL, which appears impaired in the presence of PLP. Furthermore, it may be critical for clinicians to use treatment interventions that ameliorate negative perceptions of the body post LLL, while addressing negative emotions associated with PLP.

Freysteinson et al. suggested patients receive insufficient support when observing their new body in mirrors acutely post LLL, which may contribute to the development of negative body image.[54] Mirror therapy is predominantly used to superimpose the intact limb on the amputated limb to normalize sensory feedback to the brain,[55] but mirrors may also be useful as part of a cognitive behavioral approach, where individuals are guided through observation and acceptance of their new bodies.[54] As such, future studies may investigate the impact of early, guided mirror training in both improving body image and reducing PLP after LLL.

Furthermore, there has been an increasing emphasis on using mind-body interventions to normalize the somatosensory representation of painful body parts and, consequently, reduce pain.[56,57] Graded motor imagery, a staged progression of imagery-based exercises aimed at improving sensorimotor communication between the painful area and brain using motor imagery and mirror therapy, has shown promise in reducing PLP intensity.[17] Graded motor imagery may also have beneficial effects on body image and pain hypervigilance, which may mediate exacerbations in pain intensity.[16] Virtual reality techniques have emerged as promising progressions of traditional imagery-based interventions and may successfully target impaired body representation.[58] Evidence supporting the use of mind-body interventions remains scarce, and outcomes are largely focused on reductions in pain intensity.[16] Our findings suggest other outcomes (e.g., body image, attention, awareness) may be important considerations when evaluating mind-body intervention effectiveness for addressing PLP.

Study limitations

As this study was completed remotely, clarifying questions were limited; however, this may have beneficially reduced examiner bias in completion of self-reported outcome measures. Second, given the pilot nature of this study, a priori sample size estimates were not calculated. Although a priori targets of ≥20 participants per group (while considering incomplete data sets) were established, some analyses may be underpowered; therefore, future studies may consider replicating our findings in larger samples with more variable participant characteristics (e.g., bilateral LLL, diverse PLP severities).

Given sample size limitations, associations among body image and perception outcomes and suspected covariates (e.g., age, gender, time since amputation, amputation etiology) remain unexplored. Relatedly, although post hoc comparisons suggested RLP intensity was not correlated to outcomes of interest ($\tau_b = -.03$–21, $p = .157$–.854), RLP may be a source of increased attention and stress, as it may increase prosthetic socket discomfort and inhibit successful prosthesis use.[59] Future studies may explore relationships among these factors, beyond the associations with PLP found in this study.

Finally, the scale used to capture prosthesis embodiment was informed by prior qualitative analyses[60] and designed for this study to assess perceived prosthesis ownership and functionality; future studies may consider evaluating the psychometric properties of this scale post LLL.

CONCLUSION

Adults with PLP demonstrate more negative body image, increased phantom limb attention and awareness, and reduced prosthesis satisfaction and embodiment as compared to pain-free peers. Preliminary findings support further investigation into whether body image and perception may be key areas for intervention post LLL, especially among adults with PLP. Given the psychological stigma of PLP, individuals may be hesitant to discuss their experiences with medical providers, family, or friends post LLL; therefore, as clinicians, broaching these topics is imperative to not only validate patients' experiences but also identify potential areas for intervention.

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DISCLOSURES

None to report.

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