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e , i e o e head ha ne ing in man ca e , 2 o mo e he a i , o omo e o e , e ing do age, co ec kinema ic , main ain o , e and balance, and o man all a i , nk, hi , and leg d ing e ing. I i co I in boh e onnel and e i men.³5 In ecen ea , lore limb oboic e o kele on ha e eme ged a a o en ial o e g o nd locomo o , aining, ool fo indi id al rih ne ologic condition. The o ide he in en i and do e ma ching , and a d of ca e, b, al o o ide, loading and , c, ed kinema ic rhich m I i le clinician offe. Al ho gh he facilita e fa o able heal h o, come fo , e , he ma ed ce clinician effor d ing, he a .^{4,6-9}

Va io, o gani a ion and in e iga o n he i e cien \mathbf{n} c e idence and o ide ecommenda ion, which in ence clinician' e ce ion abo, locomo o gai aining.¹⁰⁻¹⁴ Thei e ce ion a e al o in enced b hei ac ice e ing, geog a hic loca ion, aining, and knowledge. The e of obo ic e o kele on allow o e g o nd locomo o aining fo indi id al with SCI with a ing deg ee of im ai men a an eal age of ehabilit a ion when, adi ional me hod of locomo o aining a e diff c i . F, he mo e, he e de ice allow indi id al with SCI o ac ice walking in he comm ni enhancing con in i of ca e 4

ehabili a ion x hen, adi ional me hod of locomo o aining a e difi c i . F, he mo e, he e de ice allox indi id al x i h SCI o ac ice x alking in he comm ni , enhancing con in i of ca e. Al ho gh he e i ea l e idence o , o , he heal h bene of obo ic locomo o e o kele on , e, 7.15^{-191} he e i limited e ea ch on clinician ' e ec i e ega ding a lica ion fo e o kele on, e in locomo o , aining. Thi , d aim , o de c ibe clinician ' efe ence , clinical ac ice , aining , a egie , and clinical deci ion on hox obo ic e o kele on de ice a e, ed x i h e e an and ci ilian x i h SCI.



Ad ancemen in clinical açice de end on a c clic oce * he e e idence i in eg a ed in o açice and * he e clinical e e ience info m he e idence.²⁰ Fo hi ea on, clinician e eçi e ela ed o bene, and limit a ion of ehabili a ion echnologie a e im o an. Heinemann e al²¹ e amined he ai, ' e e ience ' ing oboic e o kele on fo o e g o nd * alking in foc g o . The a i de c ibed hei e e ience , e al a ion, and aining a egie * i h oboic e o kele on . Pa ici an e o ed ' ing e o kele on ima il in o, a ien and * ellne e, ing , ho gh 1 cene ' ed e o kele on d' ing in a ien ehabili a ion. A ical o, a ien e i ode con i ed of 20-30 e ion and in ol ed a lea 2 aff membe . T ea men goal incl ded anding, e ing, and gai aining. Bene, a, ib ed o' e of e o kele on incl ded h iological (ed ced ain, im o ed boy el f ncion), chological, and ocial change . The a i, no ed he i k of fall, kin i i a ion, and high a ien e eça ion . Ho i al ' ed a ied a egie fo in eg a ing oboic e o kele on in o he a e ice.

a, ib, ed, o, e of e o kele on incl. ded h iological (ed ced ain, im o ed box el f nc ion), chological, and ocial change. The a i, no ed he i k of fall, kin i i a ion, and high a ien e ec a ion. Ho i al , ed a ied a egie fo in eg a ing oboic e o kele on in o he a e ice. Al ho gh he Heinemann, d o ide elimina e idence o g ide he in eg a ion of e o kele on in o ehabili a ion e ice, a mo e de ailed anal i of he a i, 'e e ience i needed o g ide ac ice and o inform a ien e ec a ion. Thi , d add e e e ea ch , e ion : (1) Hox do clinician e al a e a o ia ene, a ien cha ace i ic, and eali ic e ec a ion ega ding obo ic locomo o e o kele on he a in ehabili a ion and comm ni e_1 ing ? (2) What aining a egie do clinician r e x i h a ien and ca egi e ? (3) What benend do clinician e cei e f om r ing e o kele on ? (4) What effe ence do clinician hat e ega ding x hich obo ic e o kele on he r e? (5) What limit a ion r o obo ic locomo o e o kele on do clinician iden if r, and x hat hat d x a e and of x a e de elo ment do clinician ecommend?

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In i, i ional e ier boa d a collabo a ing o gani a ion o ided e hical a o al. All a ici an o ided info med con en and ecei ed an hono a i m. The U.S. A m Medical Re ea ch and De elo men Command Ofice of Re ea ch Poecion, H man Re ea ch Poecion Ofice al o a o ed he o ocol.

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U ing a henomenological a oach, hi , d , ed , an i a i e

٩	e 1	Clinicians'	demographic and	robotic	exoskeleton	experience
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Demographic Characteristics	Site A	Site B	Site C	Site D	All Sites
n	10	9	8	2	29
Mean age (y)	34	37	36	32	35
Age (y) (range)	26-44	32-47	30-45	30-34	26-47
SCI clinical experience (y) (mean)	5.8	9	8.6	6.5	7.6
SCI clinical experience (y) (range)	1-12	4-13	2-22	4-9	1-22
Exoskeleton experience (y) (mean)	3.7	3.9	4.1	3.5	3.0
Exoskeleton experience (y) (range)	1-11	2-6	2-7	2-5	1-11
Sex (%)					
Women	70	67	88	100	76
Race/ethnicity (%)					
White	90	100	88	100	93
Black	0	0	0	0	0
Asian/Indian	0	0	0	0	0
>1	0	0	13	0	3
Other	10	0	0	0	3
Declined to answer	0	0	0	0	0
Hispanic/Latinx (%)					
Yes	10	11	13	50	14
Exoskeleton experience type (%)					
Research	50	0	25	0	24
Clinical	0	66	50	100	38
Research and clinical	50	44	25	0	38

cla if ing, and in e e ing da a in o code and heme, and hen e e en ing and i, ali ing da a b 3 e ea ch eam membe. We e dan ind c i e anal ical a oach o od ce he codebook ba ed on o en coding of he foc g o ine iex.² The e each eam e iex ed he coded an c i o a e ine e a ion, econcile di c e ancie among he 3 code, di o ini ial nding and make mode ca ion. Diffe an com di c 'ini ial') nding, and make mod ca ion. Diffe en team of 3 e ea che coded he emaining an c i . Tro ima on 5 e ea che coued ne emaining an c1. L's o ima code coded inde enden 1 and hen econciled diffe ence. The hi d code ead he an ci inde enden 1 and econciled he 2 ima code 'heme. When ka a coel cien did no mee o e ceed 0.80, he eam of 3 me o e ies code and modif hem o each con en and en e ine a e eliabili . Finall, he en i e eam me o e ies and ha moni e code ac o ie. Thema ic a, a ion s a me af e he 4 foc g o an ci s e e anal ed. ree anal ed.

We enhanced me hodological igo b , ing a , anda di ed, emi, c, ed mode a o g, ide and ha ing 1 mode a o cond c all foc g o . We en, ed in e iga o iang, la ion b ha ing 3 in e iga o inde enden 1 code i an c i i befo e econciling heme .

 Table 1
 e o
 demog a hic cha ac e i i c of foc g o
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 ici an
 . On a e age, clinician g e e in hei 30, edominan 1

 a a conta c age, enniciant y c c in fiel 30°, edominal i y omen and y hi e. E e ience y h SCI a ien, a e aged 7.
ea, y he ea e e ience y h e o kele on a e aged 3 ea⁵.
Pa ici an had clinical and/o e ea ch e e ience.
Table 2 o ide de ail of clinician ' obo ic e o kele on initiate on had e incended a standard of the clinician' obo ic e o kele on initiate on had e incended a standard of the clinician' obo ic e o kele on initiate on had e incended a standard of the clinician' obo ic e o kele on initiate of the clinician' obo ic e o kele

aining. One-hid o one-half of he clinician had a ained

ce î ca ion x i h a lea 1 e o kele on man fac, e. Mo x o ked in o_1 a ien e, ing and had obo ic locomo o aining e e ience x i h fe x e han 20 a ien. Clinician x ho e o ed mo e e e ience, ing obo ic e o-

kele on had g ea e comfo, ing he de ice rih a b oade ange of indi id al han did clinician rih le e e ience.

Re, l a e o gani ed b , e ion ha e ec he , c, e of he foc, g o, g ide and he anal i of foc, g o, membe, a ement. Table 3 i o gani ed o ill, a e heme f om ind c-i e coding of an c i along rih e e en a i e o e. The color mn in able 3 li, he high-le el heme, he econd color mn li, he mid-le el heme, and he hi d color mn li b heme. Shor n in a en he e a e he normal of o ni o coco ence of heme r hen he e ree no o b heme, o o ni o e occ, ence of mid-le el and , b heme. Fig, e 1 o ide a g a hical ies of heme, mid-le el heme, and , b heme f e, encie, s i h fon i e e ec ing ela i e f e, enc .

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Clinician x e e conce ned abo, a o ia ene of e o kele on , e fo ce ain a ien. A o ia ene x a ba ed on incl. ion-e cl. ion c i e ia ech ed b he de ice man fac, e , a ien goal fo , ing he de ice, ime ince inj, and e o le el of ini of inj

Well, I hink ha' o indi id al and o ma ha e ecom-menda ion and he ma q all di ega d hem beca e he j ha e hi i ali a ion of hem i ili ing an e o kele on, b q o he oin of, o know, ing i vi hin he ki chen, if ha' o onl

e 2 Clinicians' training, experience, and certifications

n	29
Years worked (mean \pm SD)	7.8±4.0
Type of RT exoskeleton experience (%)	
Rehabilitation therapy	37
Research	27
Both	37
Currently work with RT exoskeleton (%)	
Yes	83
Years worked with RT exoskeleton (mean \pm SD)) 3.3±2.7
Number of patients worked with using RT	
exoskeleton (mean \pm SD)	
Inpatient	7.0±11.0
	17.0±14.0
Unknown	0
(%)	1
(70) Ekso Biopics	60
ReWalk Robotics	47
Parker Hannifin Indego	70
Other	23
Unknown	0
Decline	0
RT exoskeleton certifications (%)	
Ekso Bionics	50
ReWalk Robotics	40
Parker Hannifin Indego	60
Other	13
Decline	3
Ekso Bionics certification level (%)	
Level 1 initial training	30
Level 2 advanced training	33
Other	0
Decline	0
ReWalk Robotics certification level (%)	07
Basic training	37
Advanced training	23
Refresher (mormal)	3
	0
Parker Hannifin Indego certification level (%)	0
Indego specialist	53
Indego trainer—clinic	30
Indego trainer—personal	27
Other	7
Decline	0
Have any of your patients purchased an RT	
exoskeleton? (%)	
Yes	33
No	53
Unknown	10
Decline	3
How many patients have purchased an RT	
exoskeleton? (%)	
1	13
2	15
5 Decline	5
Decime	3
(continue	ed on next column)

goal, $x \circ ldn'_{1}$ a anding x heelchai o en iall be a be e ale nai e fo o ? O ma be no, o knox, b' i ha ma be a lox e ech, lox e co, ale nai e fo ha one aci i if ha' o ole goal. I hink i eall de end.

۰e e e e , Clinician iden i ed cha açe i ic of a ien sho so ld be

becc priving an e o kele on, including moi a ion, gene al heal h, lea ning le, con dence, and bod as a ene.
You need omeone sho ha he in e e and sho ha a o ia e goal and se feel con den ha he de ice can o en iall deli e on ho e goal. The e on ha o be moi a ed to do sha i i that se hink he hould do in he de ice o get he bened.

In addition, clinician iden \mathbf{D} ed a ten, cha ace i tic ha migh hinde e o kele on ' e, ' ch a limited a m' engh, ' n-, i able bod, e, o a g, men a i e o noncom lian beha io.

If he e on i a g men at e o noncom lian beha io . If he e on i a g men at e j, in a eg la he a e ion, o a e no going o ', ho e g in a obo, beca e he need o be able o eall li en, o nde and he he hold, and tha o do, and hot o mee he nnel, and j, all of he echnical ', ff,

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Clinician di c, ed he need fo a ien o ha e eali ic e eça ion ega ding he ca abili ie of obo ic e o kele on . Pa ien ma ee o he in he de ice and e ec imila o come o he ma nd he e o kele on doe no o ide he fronç ion ha the e ec ed.

he e eç ed. We' e e laining ha o hem e hone l and a ing n-fo, na el x e don', e eç hi o allor o o be able o x alk, b i can ha e a lo of o he bene, incl ding o ma noice ha o' e able o con ol o 'nk be e. Yo ma noice ha o' e able o an fe a li le bi be e beca e o can ma be b ing o elf fo x a d be e and do mo e x i h o 'nk. Yo can each f om i ing. Ma be hel x i h ADL . So x e a e ing o 'f o x a d ho e o i i e, like x ha he can bene, o' of he de ice e. B' o like le hem knox ha hi i 'nfo' na el no x ha o' hink abo' o ha en. Beca' e a lo of ime he a k, I hi going o hel me x alk? And nfo' na el, o ha e o kind of make 'e ha he 'nde and ha ha' no he goal fo hem, I hink one of he ma be ba ie o hing ha x e' e had o

I hink one of he ma be ba ie o hing ha re'e had o con ide j, in gene al i beca, e i' kind of , ch a high o le con the j, in gene at i beca et kind of , ch a mgn of te de ice, when a ien ee omebod el e in i, o know, hei a oma ic kind of e on ei, well, I wan o ge in i and I wan o , oo. And coming f om ha o -ac e and oin whee we kind of know what i ac, all ake o ge one, what he ac, al e, i emen a e, o, cha e one and how eo le a e ac, all eall , ing i, he folk ha ha e, cha ed one, we, o know, ha e, o kind of manage e ec a ion a li le bi,

High-Level Theme	Mid-Level Theme	- · · · · · · · · · · · · · · · · · · ·	
(Frequency)	(Frequency)	Subtheme (Frequency)	Representative Quotes
			And so I think the – being able to walk overground with individuals who might not necessarily be able to do that without a significant amount of assistance I think is extremely valuable.
	Physical (24)		I think of all the other health benefits, too, tha again it's not well documented at this point but that's one thing that being upright and walking gives you bowel/bladder, spasticity, as people mentioned, a lot of different healt benefits that you can't get another way I thin is something to consider, especially with, yo know, taking it home, like, that might be th biggest benefit to taking it home in the long term is just from a health and wellness perspective versus a functional perspective, a least where it is at this point.
Patient experience	Realistic expectations (62)		 Whether they have true understanding about the capabilities of—the real capabilities of exoskeletons, what they can and what they cannot do, that is where a lot of the conversations really have to happen, not goin and seeing these cool marketing spots online and not hearing these really emotional, impressive stories from patients who have utilized them online but getting to the nitty gritty of, well, this is where you are and thes are your goals and this is the reality for you. And he said, well, my workers' comp offered to buy me an exoskeleton or a standing outdoor wheelchair, and he's like, I like to g hunting. I picked the standing outdoor wheelchair. He's like, I'm not – you know, as cool as this thing is, he's like, this doesn't give me what I want to be able to do. And so that was kind of like an aha, like thi guy's been in it and does great and loves it, but he's like, I don't want that. There's a very fine line between encouraging and having them run off with oh I'm doing thi because I'm going to walk. And it would be nice if every single person that we saw every day would have that opportunity, but not

• e 3 (continued)			
High-Level Theme (Frequency)	Mid-Level Theme (Freguency)	Subtheme (Frequency)	Representative Quotes
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High-Level Theme	Mid-Level Theme	Subtheme (Frequency)	Representative Quotes
Therapist experience	Benefits (28)	Subtrieffie (Frequency)	If a limiting factor in walking someone is the clinician's ability to continue to sustain the activity and not the ability of the patient to sustain the activity, then that's a huge limiting factor to the total volume that you can actually get in in a session so I think that's a great point because we can get a lot more steps in with a device that's going to help facilitate those steps than if we're manually manipulating every step. So that's also where inpatient, sometimes it's easier to get them into a robotic system that to have the necessary four people it would take to truly do a treadmill session
	Limitations (19)		But the biggest barrier is probably wounds, if they already have wounds, and the weight limit is 220. But I think one limiting thing with EKSO is tha we usually always have two therapists in case something bad happens, it's a little harder to get out
Training	Caregiver (31)		 That's a perfect person, but you also have to have the perfect support person. And so far the caregivers that our patient have chosen, like one of them was a son who, I don't know how old he was, adult son that learned the device to be his second person or a wife, um, they've all been super supportive and learned the devices right along with the patient, and come to sessions. So I think that's really facilitated their success as well. I mean, obviously they have to be physically capable of it
	Patient (40)		 And, oh, my goodness I had one person from North Carolina figure out that whole motor neuron thing, he figured out how to use the device, Level 2 training, meaning community mobility, not just in the home within the firs 2 days, completely independent. He took it to a school. He took it to a funeral. We did everything imaginable. We were on a light rail that's never been done on an exoskeleton. Like it was easier – like a true community ambulator in the device. So it's like trying to show them what the benefit: are, because we sort of know as therapists how to guide them, but sometimes they're not really sure what they're going to get out of the trials. And so it's sort of enlightening to them

e eç i e ega ding, e of obo ic e o kele on in aç ice. Heinemann e al²¹ e o ed he a i , e eç i e on, ea men goal, bene, and i k of e o kele on he a . Mo en on e al²⁶ al o foc ed on he a i , e e ience, ing he e de ice in aç ice. Th ee main heme of hei , ali ai e , d , e e (1) diñ c l lea ning o , e he e o kele on; (2) challenge of inco o a ing e o kele on in o dail life; and (3) lack of *agic b lle* effec. The a i , ho gh ha e o kele on ma ed ce h ical demand on he a i , d ing ehabili aion, b , ha he e a e ba ie , o incl ding e o kele on in aç ice, c ha calib aion ime, in eni e, aining e, i ed o, e an e o kele on, he co, of he de ice, and a ien ' comfo, and afe , ing he de ice. The al o em ha i ed ha he a i , m , manage aien ' e eç aion ela ed o he, e of e o kele on . Finding of o , d , o he e ob e aion and al o ill mina e he im o ance of , ndeanding aien ', o e fo, ing an e o kele on and he e, ing in , hich aien in end o, e an e o kele on and he e, ing in , hich aien in end o, e an e o kele on and he e, ho , an o clinical e, ing b ing diffe en e eç aion than ho e , ho , an o

- 19. E an N, Ha_iigan C, Kandilaki C, Pha o E, Cle on I. Ac_ie ca dio e i a o and me abolic e on e d ing e o kele on-a i ed x alking o e g o nd among e on x i h ch onic inal co d inj To S inal Co d Inj Rehabil 201₂;21:122-32.
- 20. G aham I, Te oe J, Gagnon M. Knog ledge di emina ion: end of g an knowledge, an la ion. In: S a S. Te oe J. G aham I, edi o . Knowledge, an la ion in health ca e: mo ing f om e idence o ac ice. 2nd ed. O fo d: Wile ; 2013.
- 21. Heinemann AW, Ja a aman A, M, mmidi e, CK, e, al. E e ience of obo ic e o kele on , e a fo, inal co d inj, model em cen e . J Ne, ol Ph. The 2018;42:2 56-67.
- 22. O'B ien BC, Ha i IB, Beckman TJ, Reed DA, Cook DA. S anda d fo e o_1 ing a_1 i a_1 i e e a ch: a_1 a_1 he i of ecommendation. Acad Med 2014;89:124 - 1. 55

- 23. Cla ke V, B & n V. Teaching hema ic anal i: o e coming challenge and de elo ing a egie fo effecti e lea ning. P chologi 2013;26:120-3.
- 24. B & n V, Cla ke V. U ing hema ic anal i in cholog . Q al Re P chol 2006;3:77-101.
- 2. Thoma DR. A gene al ind c i e a oach fo anal ing , ali a i e
- 5 e al·aion da a. Am J E al 2016;27:237-46.
 26. Mo en on WB, P kl kec A, Cha L, P e co, M, Tok n on A. The a i e e ience of aining and im lemen ing an Im le e o kele on in a ehabili a ion cen e. Di abil Rehabil 2020 J. 1 10. [E, b ahead of in]. 27. MacKa C, Hayke GA, Jaglal SB. Hoy do h ical he a i