

Physical Therapist Acceptance of a Wearable Fabric-based Sensor System (Motion Tape) for Use in Clinical Practice: A Qualitative Focus Group Study

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Abstract

Background: Low Back Pain (LBP) is a costly global health condition that impacts individuals of all ages and genders. Physical therapy (PT) is a commonly used and effective intervention for the management of LBP and incorporates movement assessment and therapeutic exercise. A newly developed wearable fabric-based sensor system, Motion Tape, is a technology that uses novel sensing and data modeling to measure lumbar spine movements unobtrusively and thus offers potential benefits when used in conjunction with PT. However, physical therapist acceptance of Motion Tape remains unexplored.

Objective: The primary purpose of this research study was to evaluate physical therapist acceptance of Motion Tape to be used for the management of LBP. The secondary purpose was to explore physical therapists' recommendations for future device development.

Methods: Licensed physical therapists from the American Physical Therapy Association Academy of Leadership Technology Special Interest Group participated. Two focus groups (N=8 total participants) were conducted where participants were presented with Motion Tape samples and examples of application data output on a poster. Informed by the Technology Acceptance Model (TAM), semi-structured focus groups were conducted and explored wearability, usefulness, ease of use, and suggestions for improvements in Motion Tape for PT management of LBP. Focus group data were transcribed and analyzed using Rapid Qualitative Analysis.

Results: For wearability, participants believed the Motion Tape could adhere for several days, with some variability due to external factors. Feedback was positive on the low-profile and universal fit, but discomfort due to wires and potential friction with clothing were of concern. Other concerns included difficulty with self-application and potential skin sensitivity. For usefulness, participants expressed that Motion Tape would enhance efficiency and specificity of assessments and treatment. For ease of use, participants stated that the application would be easy, but data management and challenges with interpretation were of concern. Physical therapists provided several recommendations for future design improvements including having a wireless system or removable wires, customizable sizes for tape, output including range of motion data and summary graphs, and adding application features that consider patient input and context.

Conclusions: Several themes relating to Motion Tape's wearability, usefulness, and ease of use were identified. Overall, physical

therapists expressed acceptance for Motion Tape's potential for assessing and monitoring low back posture and movement, both within and outside clinical settings. Participants expressed that Motion Tape would be a valuable tool for personalized treatment of LBP, but highlighted several future improvements needed for Motion Tape to be used in practice. Clinical Trial: Not applicable

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Original Manuscript

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challenges with interpretation were of concern. Physical therapists provided several recommendations for future design improvements including having a wireless system or removable wires, customizable sizes for tape, output including range of motion data and summary graphs, and adding application features that consider patient input and context.

Conclusions: Several themes relating to Motion Tape's wearability, usefulness, and ease of use were identified. Overall, physical therapists expressed acceptance for Motion Tape's potential for assessing and monitoring low back posture and movement, both within and outside clinical settings. Participants expressed that Motion Tape would be a valuable tool for personalized treatment of LBP, but highlighted several future improvements needed for Motion Tape to be used in practice.

Trial Registration: Not applicable

Keywords: Low back pain; physical therapy; physical therapist; wearable sensor; technology acceptance model; motion tape; kinesiology tape

Introduction

Low back pain prevalence and impact

Low Back Pain (LBP) is one of the world's leading causes of disability [1–3]. In 2019, there were nearly 568.4 million prevalent cases, 223.5 million incident cases, and 63.7 million cases of years lived with disability due to LBP reported globally [4]. LBP affects all ages and genders, but increases in prevalence with increasing age, peaking around 45-54 years old [4]. Approximately 70-85% of adults are expected to experience at least one episode of LBP in their lifetime [5]. Once predisposed to LBP, individuals are twice as likely to have recurrent episodes of LBP [6]. Annually, LBP in the US results in 149 million missed work days [7,8]. Total costs of LBP worldwide amount to nearly \$100 billion a year, with two-thirds of this amount due to lost wages and decreased work productivity [9].

Treatment of LBP with Physical Therapy

Physical therapy (PT) is a common and effective evidence-based treatment for LBP [7,10]. Specifically, active interventions including exercises provided by a physical therapist are effective for prevention and treatment of LBP [11,12]. During an initial examination, a physical therapist can identify musculoskeletal and neuromuscular impairments associated with the LBP problem by conducting assessment of the patient's posture and movement. Then, the physical therapist and patient can work together to promote strength, stability, and mobility with in-clinic sessions and an assigned home exercise program with the goal of decreasing pain and disability [10,13]. Monitoring the patient's posture and movement can provide a basis for determining individualized factors associated with the LBP problem which can then be addressed through targeted interventions.

Incorporation of Technology in PT

Whether at home or at work, specific movement patterns that are performed repeatedly have been identified as a significant risk factor for development and persistence of LBP [2,14,15]. These movement patterns of the low back region can be characterized by evaluating angle, velocity, and acceleration [16] and can assist in LBP diagnosis, treatment, and prevention. There are several approaches to monitoring spine posture and movement. Generally, when conducting a PT examination, clinicians visually monitor posture and movement or utilize tools that measure range of

movement like goniometers or inclinometers [17]. But an alternative approach is to use technology to help better quantify objective measures of spine posture and movement and offer potential benefits like remote monitoring [18,19] while the patient is away from the clinic.

Technologies for Monitoring Low Back Pain

To date, existing technologies used to measure spine posture and movement in research and practice are optical motion capture, inertial measurement units (IMUs), and other wearable sensors [20–22]. Despite the variety of systems available, they generally present one or more limitations. Optical motion capture systems offer great precision and accuracy in monitoring human movement. However, their applications are limited due to space needs, cost, and level of expertise needed. IMUs are portable devices that measure metrics like acceleration and orientation [23] and include a variety of wearable sensors such as accelerometers, gyroscopes, and magnetometers, making them ideal for collecting data in a free-living environment. However, when used for monitoring human movement, IMUs have several limitations including decreased accuracy and precision for measuring slow movements [24,25], difficulty with accuracy of measuring axial plane movement, inability to account for the multisegmented nature of the spine [26], and the need for multiple IMUs to triangulate posture and movement of a segment which can be cumbersome to the wearer [27].

Motion Tape

Because of limitations of existing sensor systems for measuring spine posture and movement, there is a need to explore new sensor innovations to address this issue. Ideally such an approach would be wearable, unobtrusive, and usable in a clinical environment during PT sessions as well as in a person's natural environment to support home-based care. Another desired requirement would be high accuracy while collecting posture and movement data for a prolonged period.

Motion Tape, developed by Loh and Lin[28], is a disposable, self-adhesive, skin-strain sensor system made from graphene nanosheets coated onto commercially-available Kinesiology tape (aka, K-Tape) [29–33]. Motion Tape has piezoresistive properties based on the deformation of the integrated nanosheets in the tape that makes it sensitive to strain [33]. In prior studies, Motion Tape has demonstrated stable performance under cyclic strains [33,34]. In addition, the Motion Tape sensor system has been tested on human subjects [33,34], displaying accuracy in measuring skin-strains and angles across biceps, knees, shoulders, wrists, and other various body regions when compared to IMUs and skin-strains estimated from optical motion capture systems [35]. Overall, Motion Tape offers non-invasive, comfortable, and practical skin-strain measurements and can comprehensively capture complex movements, as well as muscle engagement, when applied as a network of sensors [35].

Motion Tape for a Low Back Use Case

When used for a low back use case, Motion Tape provides a means to capture the lumbar spine's multi-segmental nature and multi-planar movements [36]. Motion Tape's low-profile and stretchable nature allows it to be worn throughout the day for all human shapes and sizes and could be suitable for use in an individual's natural environment with minimal interference to their daily activities. Motion Tape provides unique sensing streams that can be used in machine learning and artificial intelligence models to optimize inferences related to management of LBP. Specifically, Motion Tape for a low back use case can address several key issues in a physical therapist's management of LBP, including: expanding on the level of detail available during the

clinical assessment of posture and movement; assessing spinal posture and movement in a free-living environment; use for promotion of engagement, adherence, and precise performance of a prescribed home exercise program; and using the patient's response to treatment to make informed decisions for future treatment or other patients [37]. While there are several potential benefits that Motion Tape may add to personalized healthcare for LBP, the acceptability of Motion Tape among Physical Therapists has yet to be assessed.

Physical Therapist Acceptance of Motion Tape

Success of this device is dependent on user acceptance, or one's belief that the device will help them perform their job better (i.e., perceived usefulness) and that the device's performance benefits outweigh the effort of using the device (i.e., perceived ease of use) [38]. Thus, it is vital to understand physical therapists' perspectives on Motion Tape and willingness to use it in their practice, to inform future developments and improvement of the technology.

Problem Statement

The primary purpose of this research study was to evaluate physical therapist acceptance of Motion Tape for the management of LBP. The secondary purpose was to explore physical therapists' current needs and recommendations for future development of Motion Tape.

Methods

Device Description and Stage of Development

For this study, a prototype of Motion Tape and example of data streams from the application for a low back use case were evaluated by licensed physical therapists. The Motion Tape samples evaluated in this study included the Motion Tape sensor system with conductive wire leads connected to both sides of the sample (Figure 1).



Figure 1. Motion Tape sample with conductive wire leads given to the physical therapists for evaluation.

Study Design

This exploratory, qualitative study was designed to explore physical therapist acceptance of Motion Tape to provide a basis for future device development (Figure 2). The study was conducted from a constructivist point of view, with the goal of gaining insightful accounts and narrations of clinicians' lived experiences with technology and patients, rather than identifying an absolute truth [39]. We utilized semi-structured focus groups (FG) that incorporated human factors considerations to uncover real-world needs and obstacles, and to ensure that the development of the sensor system can be informed by real-world physical therapy clinical needs.

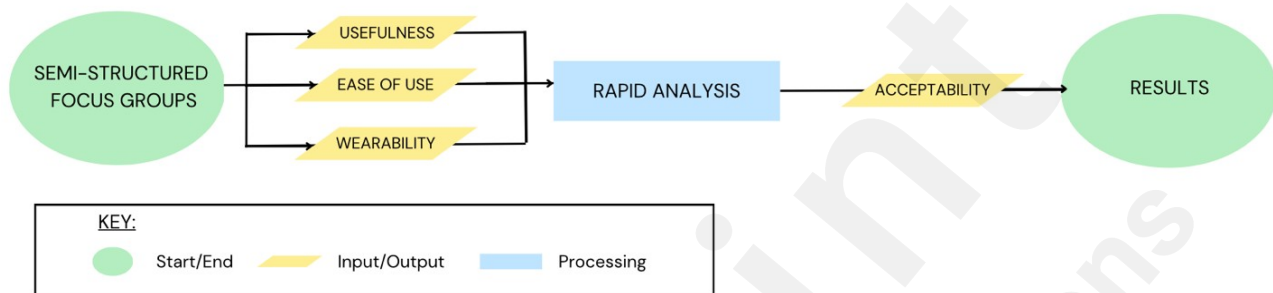


Figure 2. Study Design Overview - Evaluation of Motion Tape Acceptability.

Theoretical Framework and Constructs

The Technology Acceptance Model (TAM) framework was used in this study to assess two determinants of user acceptance, or willingness to use, a technology: (1) perceived usefulness and (2) perceived ease of use [38, 40]. An additional factor of wearability was also assessed to examine physical therapists' perceptions of patient-centered issues that would affect whether the device would be worn [42]. Recommendations for future improvements were also investigated to gather insight on data, device, and application developments clinicians would like to see for Motion Tape.

Perceived usefulness was defined as the degree to which the use of Motion Tape would enhance the physical therapists' management of LBP [39–42], and was assessed with the following constructs: (1) productivity, (2) effectiveness, (3) ability to make their job easier, and (4) benefits to PT treatment and recovery. *Perceived ease of use* was defined as the degree to which the use of Motion Tape would be effortless when used for managing LBP [39–42], and was assessed with the following constructs: (1) how easy it would be for physical therapists to learn how to use it, (2) what level of instruction would physical therapists need to use it, and (3) how clear and understandable Motion Tape was in its current state. *Wearability* was defined as the degree to which Motion Tape would fit well and be comfortable for patients to wear on their back [41] and was assessed based on (1) adhesion, (2) fit, (3) feel, and (4) how comfortable physical therapists would feel about applying and prescribing Motion Tape.

Participants and Setting

This study was conducted at the American Physical Therapy Association's (APTA) Combined Sections Meeting (CSM) (San Diego, CA) on Feb 24, 2023. Participants were recruited by sending study information by email to physical therapists who were members of the APTA Academy of Leadership Technology Special Interest Group. Members also were offered an opportunity to participate when they attended the Technology Special Interest Group in-person meeting at the APTA CSM. Individuals were included in this study if they were a licensed physical therapist and were

excluded from participating if they were unable to respond to questions in English. Eight physical therapists were eligible and agreed to participate in two focus groups of 4 clinicians each. A sample size of 8 people, in 2 focus groups, was considered adequate for this qualitative study to provide adequate variability and data saturation [43], and to provide a basis for device improvement. Additionally, after data from the two focus groups were collected and analyzed, data was deemed saturated (i.e., no new themes or codes were generated) and no further focus groups were needed. The study protocol was determined to be exempt by the San Diego State University Institutional Review Board (IRB). Each participant provided written consent prior to participating.

Methods of Focus Groups

A focus group guide (Appendix A) was used to lead the group's discussion. The focus group guide was developed by investigators (AL, PD, SPG) to be semi-structured with open-ended questions to explore the participants' perspectives on the usefulness, usability, and wearability of Motion Tape and to gather insight on future improvements for the sensors and data visualization (Table 1). A template of the focus group guide was piloted with a Doctor of Physical Therapy student and a physical therapist at San Diego State University to ensure credibility [44]. General domains for each construct were pre-specified to correspond with each interview question. Domains were defined based on the TAM framework and included perceived usefulness and perceived ease of use. An additional domain of wearability also was assessed.

Focus groups were conducted by AL (a female MS student investigator) and PD (a female PhD student investigator). Reflexivity was maintained by the research team by discussing assumptions and biases that may influence how the clinicians responded to the focus group moderators, who were not licensed physical therapists. Because SPG is a licensed physical therapist and member of the APTA, she was able to provide valuable insight during development of the interview guide, analysis, and interpretation to ensure credibility of findings [44].

Table 1. Guiding Questions from the focus group guide

Perceived Wearability (W)
● How secure do you think the Motion Tape adhesive will be? [W-adhesion] ● To what degree do you think these sensors would fit your patients' anatomy (i.e. their low back)? [W-fit] ● To what degree do you think your patients would feel the sensors on their back? [W-feel] ● How do you predict the Motion Tape Sensors would feel when being removed? [W-feel]
Perceived Usefulness (U)
● To what degree would the usage of Motion Tape sensors affect how quickly you can assess your patient's posture, movement, and/or exercise performance? [U-efficiency] ● How effective do you think the Motion Tape sensors will be to capture valid data on your patients in the clinic? [U-effectiveness] ● How effective do you think the Motion Tape will be to capture valid data on your patients in their daily routine and normal environment? [U-efficiency] ● To what degree would the usage of Motion Tape sensors affect the level of difficulty of your job as a clinician/PT? [U-make job easier] ● What features, if any, would make the Motion Tape more useful to you? [U-

useful]

Perceived Ease of Use (EU)

- How easy do you think it would be to learn how to use Motion Tape? [EU-easy to learn]
- How comfortable would you feel prescribing Motion Tape to a patient to monitor their movements at home? [EU-comfort in usage]
- What level of knowledge do you think a clinician/PT would need to use the Motion Tape? [EU-clear and understandable]
- How easy/difficult do you think it would be for a clinician/PT to apply the Motion Tape to the patient's back? [EU-easy to use]
- What features, if any, would make the Motion Tape easier for you to use? [EU-easy to use]

Focus groups were anonymized; each participant was assigned a color as a name to ensure confidentiality. Each focus groups lasted approximately one-hour and were recorded on digital voice recorders (Olympus Voice Recorder, WS-853). Prior to asking the participants questions, investigators gave each participant a sample of Motion Tape. Participants were then oriented to a poster that displayed the Motion Tape placement and application data output streams (Figure 3).

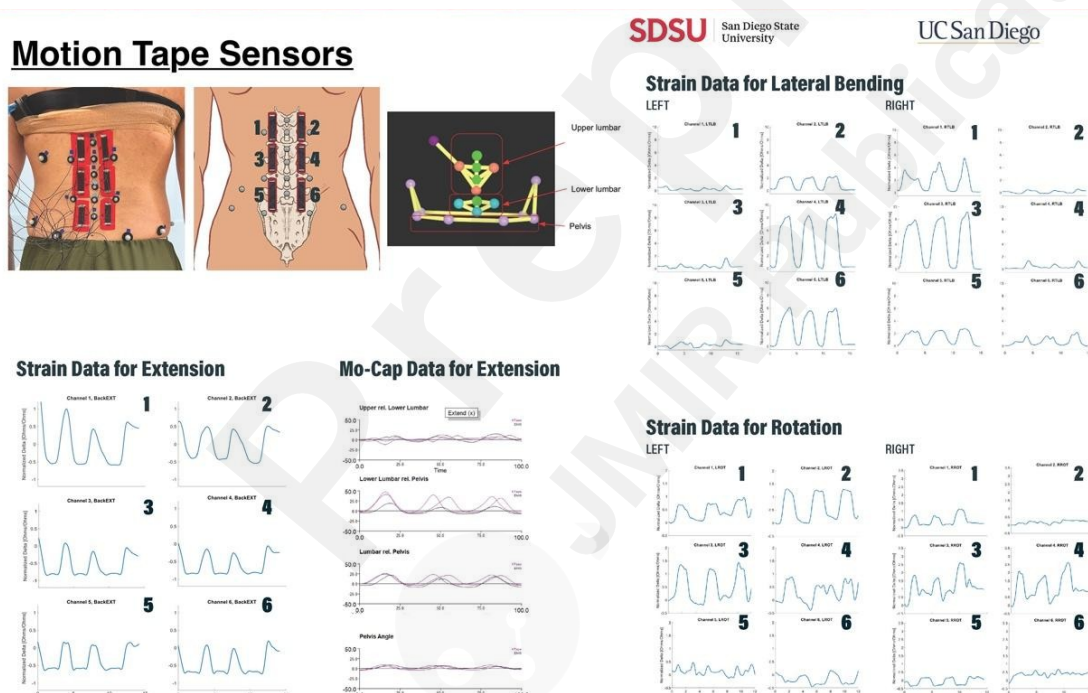


Figure 3. Poster of Motion Tape placement and application data output for a low back use case. The top left photo and figures display the laboratory set up with 6 pieces of Motion Tape and several optical motion capture markers on anatomical landmarks of the lumbar spine. The graphs in the lower left corner display: 1) purple - the kinematics for extension in degrees, captured by the optical motion capture system [reference standard], and 2) blue - the normalized strain data for extension, captured by the six Motion Tapes. The blue graphs in the upper right corner display the normalized strain data for right and left lateral bending from the six Motion Tapes. Last, the blue graphs in the lower right corner display the normalized strain data for right and left rotation from the six Motion Tapes.

Data Processing and Analysis

All focus group audio data was downloaded to a HIPAA-compliant lab server, accessible only to research staff and removed from the digital voice recorder. Recordings were later transcribed, first using computer-based transcription (Microsoft Word). An investigator then checked and verified each transcription by listening to the original audio and reviewing and correcting the computer-based transcription.

Considering the need for timely feedback in the sensor development process, we took a Rapid Qualitative Analysis (RQA) approach to explore themes on acceptability and wearability of Motion Tape [45]. RQA was conducted by three investigators to assess the interview responses effectively and efficiently and to identify major themes. Codes and themes for the RQA were deductively developed based on the TAM framework and the study objective [42]. We then used an inductive approach to generate RQA codes and themes, allowing for quick sorting of focus group dialog.

To ensure rigor and consistency of the method, a constant comparative approach with investigator triangulation was used at each stage [46]. First, the three investigators independently completed a summary report for each focus group with quotes and relevant topics under the respective themes and codes. Once the individual coding and summary reports for both focus groups were completed, the investigators consolidated them into a combined rapid analysis summary report for each focus group, unifying themes, and reconciling discrepancies by consensus through discussion. Summary reports for each focus group were then transferred into a matrix where each row was a participant quote, and each column was a domain. From this matrix, investigators identified underlying themes and subthemes between the two focus groups.

Results

Eight physical therapists (5 male, 3 female), ages 47.5 ± 5.6 years participated. Participants reported obtaining physical therapy degrees ranging from a bachelor's degree to a Doctorate in Physical Therapy, had 20 ± 8.5 years of clinical practice experience, and most reported practicing in an outpatient orthopedic setting. Five participants reported having advanced doctoral degrees (3 Ph.D., 2 Ed.D.).

The qualitative results from the focus groups were organized using the TAM model for acceptance of the Motion Tape [38,40-42]. Data were organized by the 3 main domains relevant to user acceptance (perceived wearability, perceived usefulness, and perceived ease of use) and 21 subthemes (see Table 2). Subthemes were further designated using "positive", "negative", and "neutral" valences. Subthemes with a positive valence were those that the focus group participants perceived as a positive attribute of Motion Tape. Subthemes with a negative valence indicate that focus groups perceived the attribute as negative. Subthemes with a neutral valence indicate those that the focus group participants perceived the attribute as neither positive or negative.

Table 2. Themes (3), subthemes (21), and valences of user acceptance of Motion Tape.

	Theme 1: Perceived Wearability
Valence	Subthemes
Positive	Motion Tape has a small universal fit.
	The feeling of Motion Tape on the skin would decrease over time.

Negative	Patients may feel Motion Tape's wires snagging or sensors rubbing on clothes.
	Motion Tape does not consider those with skin sensitivities.
Neutral	Motion Tape adheres for 3-4 days, but may adhere less due to external factors.
	The feeling of Motion Tape being removed depends on the physical therapist.
Theme 2: Perceived Usefulness	
Valence	Subthemes
Positive	Motion Tape could increase specificity.
	Motion Tape could be effective for diagnosis, management, and monitoring of LBP.
	The feeling of Motion Tape and the awareness of Motion Tape monitoring would increase adherence to a home exercise program.
	Motion Tape would be beneficial in telerehabilitation and hybrid sessions.
	Motion Tape could increase physical therapist's awareness of pain source.
Negative	Motion Tape brings legal concerns with data responsibility.
	Motion Tape's reliability could be affected by external factors.
Neutral	Motion Tape could increase efficiency of assessments, but setup could take up more time.
Theme 3: Perceived Ease of Use	
Valence	Subthemes
Positive	Motion Tape would be easy for a physical therapist to apply.
Negative	Motion Tape has too much data to sift through.
	Motion Tape data is hard to interpret in its current state.
	Self-application of motion Tape would be difficult.
	Motion Tape is single use.
Neutral	Prescription of Motion Tape is subjective to many factors.
	The user interface would dictate how much knowledge would be needed to use Motion Tape.

Domain 1: Perceived Wearability

Regarding perceived *wearability*, most physical therapists were familiar with commercially available kinesiology tape. Thus, their thoughts on perceived wearability reflected their experience with kinesiology tape. For example, physical therapists expected Motion Tape to last about 3-4 days. One physical therapist mentioned,

"Oh, I've used the K-Tape for four days before it started peeling off. Sometimes it lasts more than five days actually. Three to four days I think is average." (FG1)

However, some physical therapists clarified that the *longevity* of Motion Tape's adhesion depends on several factors. For example, two physical therapists expressed that,

"How secure it is depends on a lot of factors, like moisture on the skin. It depends on not just moisture, but how clean your skin is and how much hair is on the skin".
(FG2)

"Some of them, specifically on the low back, tend to have more oily skin, and that

depreciates the life of the tape” (FG1)

For the *fit* aspect of wearability, physical therapists also believed that Motion Tape’s size was small enough to be universal to the wearer and the placement location. Two of the physical therapists expressed,

“In my experience with tapes like this, it fits most of the clientele that I’ve worked with, both inpatient and long-term post-acute” (FG1)

“If it was that little strip, I think it would be great to use anywhere” (FG2)

For the *feel* aspect of wearability, generally physical therapists felt that patients would feel Motion Tape at first when applied, but would become less aware over time until the tape starts to peel off.

“They’d know that they’re there, and they’d probably become less aware of over time.” (FG1)

However, physical therapists generally felt that with Motion Tape’s current design, patients would *feel* the wires snagging or the sensors rubbing on clothing. One physical therapist explained it as,

“So contraptions with wires will always have that uncomfortable feeling. Always. But if you go the wireless route, then probably after two days, the patient will be more comfortable until the tape starts peeling off. However, what I’m wearing right now, something that goes above my PSIS, if I go to the bathroom or do something, I’m going to, it’s gonna move around, it might get pulled on it by my clothes.” (FG1)

When removing Motion Tape, physical therapists said it was quite variable in how the removal process would feel to the patient. Some physical therapists felt like it was subjective to how the therapist removed the Motion Tape and how much hair or oil the subject has on their skin. One physical therapist explained it as,

“I’m just thinking of whoever is taking it off. You know, like, it depends on you, like, some people just rip. And some people are just gentle. So subjective. So it depends on the training of the therapist and concern if they’re empathetic to our patients.” (FG1)

There were some wearability concerns the physical therapists brought up during the focus groups. One concern was about how patients with skin sensitivities would be able to use Motion Tape. One physical therapist asked,

“For those with skin allergy. Can you put an under wrap under this?” (FG1)

Domain 2: Perceived Usefulness

Physical therapists expressed mixed feelings about whether Motion Tape would increase their efficiency with assessments of lumbar spine posture and movement. Some expressed that if all they had to do was apply the tape, then there would be increased efficiency, stating,

“If it’s easy to objectively document, by understanding the graph, I think it’s a night and day difference versus getting into the goniometers and doing manual assessment. Instead, you put on the tape, ask the patient to rotate their trunk, lean

forward, reach forward, extend their back. And then if I have it digitally by email or direct messaging, it would save a bunch of time.” (FG1)

But others felt it would slow efficiency. One physical therapist explained that,

“Regarding the speed of assessment, I would be a little doubtful. I think by the time that you took this and you put it on the patient, you hooked up all the wires to it, you did the calibration, if you need to do a calibration, it might take just as long as doing an assessment. I would have concerns around the accuracy of this, to give you a number, an accurate range of motion, particularly for things like rotation. But if the data was convincing that everyone, if it was validated for everyone that gave you an accurate number, I think it could improve the quality of assessment.” (FG1)

One physical therapist felt that for the in-clinic assessments, Motion Tape would improve specificity, stating,

“I don't feel like it (Motion Tape) would improve speed, it would improve specificity.” (FG2)

Physical therapists also mentioned that they could envision Motion Tape would be useful for self-management and remote monitoring when used in combination with in-clinic physical therapy. One physical therapist mentioned that the ability to monitor them outside the clinic would be very meaningful.

“That's the best place to actually observe them, their normal environment. If they're in therapy, they're being observed, coached, cued by a skilled clinician. Their performance is definitely going to be different. So if they're at home, and we're able to monitor them at home, I think the treatment will be more, and your adjustment and progression will be more meaningful” (FG1)

Some physical therapists suggested that having patients wearing these sensors would increase their awareness of being monitored and thus, increase engagement and adherence to the home exercise program, stating,

“I think that what it has to offer is improving... adherence with our programs. I think that's your potential” (FG1)

“When you tell someone, I'm looking at your posture right now, you change (gesturing to posture). If they think you are watching, they'll do better.” (FG1)

In fact, physical therapists expected patients to have a phenomenal experience with Motion Tape when used in a hybrid setting, stating,

“I think to his point that if it's applied properly in the clinics, it's hybridized, and you can take a call, and there's no technical involvement on the patient side, and all they do is open up the app, they'd have this really phenomenal experience.” (FG2)

Specifically, several physical therapists expressed that Motion Tape would help with identification of postures and movements in free-living environments that provoke pain, allowing for more meaningful interventions.

“I think for it to be very useful. It would have to compare with the app where you've got user input as to what's going on... where he's got these flags and the data that was pain here, pain here, pain here, and you can look, you know, to the periods of time before that.” (FG2)

Some physical therapists did have some concerns about the usefulness of Motion Tape. One physical therapist expressed legal concerns with data responsibility, specifically that,

“As long as you collect data, someone's then responsible for it. So who's going to look at it? What's the liability then that person takes on by having that information? ... if something goes wrong, and the therapist hasn't looked at the data, I'd like to know, are they liable?” (FG1)

Another concern was knowing what external factors affect Motion Tape's signal and data reliability, mentioning that utilization of Motion Tape in practice was,

“Gonna depend on the reliability of the data” (FG2)

Several physical therapists felt that there were a variety of variables that might affect the reliability of the signal or data. They expressed,

“And what other factors affect them, the sensors, as far as humidity, water, other environmental factors that might affect it? You know, what if they have a compression garment around the trunk, for example, does that affect the sensors?” (FG2)

“Whether, getting it wet and getting so some things on it changes the conductivity, and therefore the calibration over time” (FG2)

“You get variability in the readings based on amount of tension that people put on it when they applied it.” (FG2)

“Whether that's different from person to person because of different makeups morphology” (FG1)

Domain 3: Perceived Ease of Use

Physical therapists felt that it would be easy to apply Motion Tape, given their background knowledge in human anatomy. A physical therapist stated,

“You would need to know basic clinical knowledge of the application for where to look for the muscles, you know, right. So, they need to be clinician to have knowledge of the body” (FG2)

When asked if they would feel comfortable using Motion Tape with their patients, there were mixed responses among physical therapists. Some mentioned it would depend on “cost and buy-in” (FG2), or how it was going to be “incorporated into the plan of care” (FG1). One physical therapist even explained the variability as,

“Depends on the situation, honestly. I mean, I have some families that I'll show them how to do the application. And I'll see them three weeks later, and they've reapplied four times and done it great. And then I've seen others that I'm like, ‘Oh, no! This is nope.’” (FG2)

There were also several concerns about the ease of use. Two physical therapists felt that they would have challenges with ease of use, specifically regarding interpretation of the data,

“I think in its current form, easy to apply. Hard to interpret” (FG1)

“It depends on the interface and how much it interprets the points. The tape will be easy, but it's all the other pieces” (FG2)

Additional concerns about the ease of use included that the amount of data presented was excessive, and the type of data displayed was difficult to interpret. The physical therapists expressed a desire to see values displayed for range of motion in degrees rather than resistance in ohms.

“I think I'm probably realistically just correlated with what they report has been painful. Because I don't know that I've ever been so interested in all of that. Like, it might be too much data. For a patient, like I don't necessarily need to know their range of motion during every single activity, I need to know when it is relevant to them. And when it is impacting whatever condition they're here for.” (FG1)

“And again, I think for a clinician, it's going to have to be meaningful data. It's gonna have be Range of motion data not ohms” (FG1)

“So then, conceivably, would it be helpful instead of giving you normalized strain, ... if they could interpolate it, would convert this over to degrees of rotation and flexibility?” (FG2)

“If you could get range of motion kind of information, I think that would be great.” (FG2)

Another concern was about how challenging self-application would be for patients.

“How are people actually going to apply this on their own, someone that doesn't know how?” (FG2)

And lastly, another concern was that Motion Tape is a single use product. One physical therapist explained the challenge of a single use product as,

“Okay, now how about waste? So it's like a single use thing? Now I'm gonna throw in a whole planet into this is single usage. Or can you reapply?” (FG2)

Future Recommendations

Future recommendations from the physical therapists were organized into three categories (Table 3): data, physical features, and application features.

Table 3. Themes (3) and subthemes of future recommendations for Motion Tape.

Theme 1: Data Recommendations
● Motion Tape data should be easy to read at-a-glance. ● Motion Tape data should include morphology contribution. ● Physical therapists should be aware of factors that affect Motion Tape data.
Theme 2: Physical Feature Recommendations
● Motion Tape should be made wireless or with removable wires.

- Motion Tape should be made reusable.
- Motion Tape should be customizable in length.

Theme 3: Application (App) Feature Recommendations

- Motion Tape App should include BMI input.
- Motion Tape App should include input for a patient's change in activity.
- Motion Tape App should allow flagging events.
- Motion Tape App should include comparative data.

For the *data recommendations*, physical therapists expressed that data should be summarized in at-a-glance graphs with one overall meaningful number, reflecting range of motion. They would also like to know how the data changes person-to-person due to morphology and how external factors (water, application stretch variability, and skin movement) affect the data. Additional data that would be useful to their job included comparative data, graphs with a color scale, and information about muscle activation. One focus group expressed the following,

“... take a baseline and have them rotate from that position and determined by the volume strain, whether they are tension either degrees, or even if it's yellow, green, yellow, red, like if they're moving within if they can't pinpoint it specifically, but you know, within a range, would that be helpful?” (FG2)

“I think even just having comparative data would be helpful, right? Because, you know, I keep telling my students, ‘Don't tell me, “I want to increase range 10 degrees”’. Because that doesn't tell me, ‘Can they walk?’. Right? But, ‘Are they doing better now than they were doing when we started?’ That's useful. So even if we get baseline data that could be translated into amount of motion and then follow up data that says, ‘hey, it's more, it's more fluid, it's better, it's whatever’. I think that can be really useful. Now I know the payers are gonna want, how much rotation did you get? How much lateral flexion did you get?” (FG2)

“And I think beyond the range of motion, I work in neuro. I think just like muscle activation would be interesting, you know, like, how much activation did you get today, for example, versus six weeks ago, post stroke or, you know, spinal cord or something? I think that would be really interesting just to see the firing muscle activation. And on the flip side, and I don't know if that's possible, but looking at specificity. Could that be something to monitor changes in specimen specificity? Post- X Y & Z intervention, right? That could also be interesting. So it's not really about range of motion, we're also activity known as firing or not?...” (FG2)

For *physical features* recommendations, physical therapists wanted a way to mitigate the wires, either moving to a wireless system or making them removable. Physical therapists were also concerned about the limited stretch of the short pieces of tape as it would not be applicable to typical kinesiology tape use and recommended making the length customizable to the physical therapists' need. Physical therapists were also concerned about Motion Tape's single use application and were curious if it could be reusable to reduce waste.

“Again, I'm thinking like, in the future, no wires, you've got a strip of graphene that you could customize length to, with those couple millimeters around the edge. And if we wanted a whole length, we cut whole lengths. And if we want segments, we can cut segments. And it feeds the data to the app somehow tailor it to

someone's body.” (FG2)

“So you can imagine that maybe something like this could be a roll of tape. Yeah, the width of duct tape. And there's actually two pieces on this roll. There's one section, that's the conductive piece, that you can cut it to length, and then next to it there are maybe there's a wire section, that's conductive tape that you can pull off and put on the ends of whatever you choose. So you get one roll of tape. And then one of them is the is the graphene is the other piece that you tear off to the appropriate length is the conductive tape that connects it to the box. And then it's a solution, you can customize length and you have your conductive piece and then your graphene” (FG2)

For future application feature recommendations, physical therapists expressed a need for the capability to input factors such as body mass index, activity changes, “flags” for events, and changes in pain to help label, compare, or contextualize the data.

Discussion

There is an existing gap in the research between rehabilitation device development and evaluation of clinicians' acceptance of such devices. Most existing studies have considered patient or user satisfaction [47,48], while others that consider the clinician's perspective have not specifically evaluated sensors for measuring spine posture and movement [49,50]. In the current study, several themes relating to physical therapists' perspectives on Motion Tape's wearability, usefulness, and ease of use for a low back use case were identified.

Domain 1: Perceived Wearability

One of the most common challenges for wearable sensors is ensuring they are unobtrusive to the wearer's natural movement and environment [39]. The small form and fit of Motion Tape was considered by physical therapists to be ideal for a wearable sensor. However, similar to previous research, the wires in the current design were considered not ideal [37]. Research has shown that wireless technologies tend to be more widely used in many fields, especially in the field of wearable devices for healthcare [51]. Thus, a future iteration of Motion Tape without wires would be considered optimal. Based on feedback from physical therapists, wearability for people with skin sensitivities also should be considered. Prior studies have shown that skin irritation is the most common concern when using kinesiology tape for extended periods of time [52,53]. Thus, future studies should explore whether a medium or substrate can be used under Motion Tape to mitigate skin irritation, possibly as an extension of recent work that integrated Motion Tape with elastic fabric for respiration monitoring [54].

Domain 2: Perceived Usefulness

There were mixed feelings among physical therapist participants about how efficient Motion Tape would be in the clinic. Overall, most physical therapists felt that Motion Tape would increase the specificity of their assessments, a characteristic that has been shown to be beneficial for LBP diagnosis and treatment [55]. Furthermore, Motion Tape's ability to monitor patient's movements remotely was considered beneficial as this feature may increase adherence to home exercise programs, which an important component to effective treatment for LBP [56,57].

Domain 3: Perceived Ease of Use

Based on physical therapists' perspectives, Motion Tape would be easy to apply, but data would be difficult to interpret. Creating a device that is easy to use and understand is crucial because it predicts consumer usage behavior [38,42]. Recommendations included changing the units of the data to units that physical therapists are more familiar with (i.e. degrees of range of motion) and creating an application that requires minimal time for the physical therapists to use. These changes may promote increased device usage and acceptance in PT.

Future Recommendations

Based on clinician feedback, Motion Tape appears to be a promising new technology that could be used for monitoring lumbar spine posture and movement in the management of patients with LBP. Future device development will be needed to address clinician recommendations from the current study in the domains of wearability and ease of use. Additionally, future studies will be needed to validate Motion Tape in laboratory, clinical, and free-living environments and to investigate patient acceptance of Motion Tape.

Limitations

One limitation to this current study is that participants were physical therapists who were part of a Technology Special Interest Group and are likely to be more receptive to using technology in practice. Thus, the current study's view of Motion Tape acceptability may be biased in favor of Motion Tape's ease of use, usefulness, and wearability. Future studies should also assess the acceptability of Motion Tape for clinicians who don't regularly use technology in their practice. A second limitation is that the physical therapists were not presented with active samples of Motion Tape with live data streams in the application. Instead, participants were given inactive samples of Motion Tape and presented with a poster with examples of application data streams. Future studies should provide an opportunity for physical therapists to apply Motion Tape to a person and use it with the application interface. Last, there was a potential for investigator bias in the interpretation of the results, as the several investigators of this study are actively working on the development of this device. However, two of the three investigators conducting data analysis were outside of the primary research team.

Conclusions

Physical therapists expressed overall acceptance of Motion Tape for its potential to monitor and assess low back posture and movement, both within and outside clinical settings. Physical therapist participants expressed that Motion Tape would be a valuable tool for personalized treatment of LBP, but highlighted several future improvements needed for Motion Tape to be used in practice.

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Conflicts of Interest

Co-author Kenneth J. Loh is a co-founder of JAK Labs, Inc., a company that may potentially benefit from the research results. JAK Labs intends to commercialize Motion Tape for the physical therapy and rehabilitation market, among other markets. The terms of this arrangement have been reviewed and approved by the University of California San Diego in accordance with its conflict of interest policies.

Abbreviations

APTA: American Physical Therapy Association's

CSM: Combined Sections Meeting

DAQ: Data acquisition

EMG: Electromyography

FG: Focus group

IMU: Inertial measurement units

LBP: Low back pain

Mo-Cap: Motion capture

PT: Physical therapy

ROM: Range of motion

RQA: Rapid Qualitative Assessment

TAM: Technology acceptance model

Appendix 1

Focus Group Guide.

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Supplementary Files

Multimedia Appendixes

Kinesiology Tape Sensor Feedback Survey was distributed.

URL: <http://asset.jmir.pub/assets/b76ab4f5c11d095054e3277219382a31.docx>