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THE BARRIERS AND FACILITATORS FOR WIDESPREAD USING SURFACE ELECTROMYOGRAPHY IN CLINICAL PRACTICE: A CROSS-SECTIONAL STUDY IN TURKIYE

ORIGINAL ARTICLE

ABSTRACT

Purpose: Surface electromyography (sEMG) is a non-invasive tool for understanding the mechanisms of neuromuscular systems, which provides very useful and important quantitative electrophysiological information as part of evidence-based practice. The sEMG has many applications across a wide variety of fields (e.g. in neurophysiology, physiotherapy, biofeedback, gait analysis, ergonomics, occupational medicine, neurorehabilitation, etc.). Although there are a great number of publications, books, tutorials, and advancements in sEMG, there remains a gap characterized by its lack of clinical acceptance. This study aimed to investigate facilitators and barriers to the widespread use of sEMG among clinicians.

Methods: An online survey with 46 items was conducted to potential practitioners of sEMG including medical doctors, physiotherapists, and non-clinical researchers. Descriptive statistics and cross-tabulation tests were employed.

Results: This study found that sEMG did not have high clinical acceptance despite a common perception of its clinical potential and benefits. It has been commonly used for research purposes. The major barriers were found as a lack of knowledge and experience about sEMG signals and systems due to the poor educational background of sEMG. When comparing the purpose of using sEMG, there were statistical differences in diagnosis (p=0.002) and research (p=0.004) but no differences in treatment (p=0.103). Significant statistical differences were also found among participants who took an sEMG course and those who did not (p=0.009).

Conclusion: The findings indicate that multidisciplinary bachelor's and master's programs, like a Dutch Model, are needed because advances in sEMG require new professional skills with medical and technical knowledge.

Keywords: Clinical Acceptability, Health Education, Healthcare Professionals, Medical Technology, Surface Electromyography

YÜZEY ELEKTROYOGRAFİSİNİN KLİNİK UYGULAMADA YAYGIN KULLANIMINA YÖNELİK ENGELLER VE KOLAYLAŞTIRICI FAKTÖRLER: TÜRKİYE'DE KESİTSEL BİR ÇALIŞMA

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Yüzey elektromiyografisi (sEMG), nöromüsküler sistemlerin mekanizmalarını anlamaya yönelik kanıta dayalı uygulamanın bir parçası olarak çok yararlı ve önemli niceliksel elektrofizyolojik bilgiler sağlayan invazif olmayan bir araçtır. sEMG'nin çok çeşitli alanlarda (örneğin nörofizyoloji, fizyoterapi, biyolojik geri bildirim, yürüyüş analizi, ergonomi, mesleki tıp, nörorehabilitasyon vb.) birçok uygulaması vardır. sEMG'de çok sayıda yayın, kitap, eğitim ve ilerleme bulunmasına rağmen klinik kabulündeki eksikliği ile karakterize edilen bir boşluk bulunmaktadır. Bu çalışma, sEMG'nin klinisyenler arasında yaygın olarak kullanılmasının önündeki kolaylaştırıcı ve engelleyici faktörleri araştırmayı amaçlamıştır.

Yöntem: Tıp doktorları, fizyoterapistler ve klinik dışı araştırmacılar da dâhil olmak üzere potansiyel sEMG uygulayıcılarına 46 maddelik çevrimiçi bir anket uygulandı. Tanımlayıcı istatistikler ve çapraz tablolama testleri kullanıldı.

Sonuçlar: Bu çalışma, sEMG'nin klinik potansiyeli ve faydalarına ilişkin ortak algıya rağmen yüksek klinik kabulüne sahip olmadığını buldu. Yaygın olarak araştırma amacıyla kullanılmıştır. En büyük engellerin, sEMG' nin zayıf eğitim geçmişi nedeniyle sEMG sinyalleri ve sistemleri hakkında bilgi ve deneyim eksikliği olduğu bulundu. sEMG kullanım amacı karşılaştırıldığında, tanı (p=0,002) ve araştırma (p=0,004) açısından istatistiksel farklılıklar vardı ancak tedavide herhangi bir farklılık yoktu (p=0,103). sEMG kursu alan ve almayan katılımcılar arasında da anlamlı istatistiksel farklılıklar bulundu (p=0,009).

Tartışma: Bulgular Hollanda Modeli gibi multidisipliner lisans ve yüksek lisans programlarına ihtiyaç duyulduğunu göstermiştir. Çünkü sEMG'deki ilerlemelerin tıbbi ve teknik bilgi ile birlikte yeni mesleki beceriler gerektirdiğini göstermektedir.

Anahtar Kelimeler: Klinik Kabul Edilebilirlik, Sağlık Eğitimi, Sağlık Profesyonelleri, Tıp Teknolojisi, Yüzey Elektromiyografisi

INTRODUCTION

Surface electromyography (sEMG) is a non-invasive tool for understanding the mechanisms of neuromuscular systems. It provides very useful and important quantitative electrophysiological information for the diagnosis of disorders, the planning and the assessment of the outcomes of therapeutic interventions, the prognoses, and various aspects of the person's health status and functional limitation as part of evidence-based practice (EBP) (1). The sEMG has proliferating applications across a wide variety of fields, such as in neurophysiology, physiotherapy, biofeedback, gait analysis, human-machine interfaces, robotics, ergonomics, occupational medicine, neurorehabilitation, art, etc. (2). Although there are many publications, books, tutorials, and papers on the technological advancements of sEMG, the technique has limited clinical use among clinicians, and many challenges remain still unresolved (3-5). Unlike both electrocardiogram (ECG) and electroencephalogram (EEG) methods, clinical acceptance of sEMG has not yet reached a high level and varies according to application fields and education models in the countries.

The lack of acceptance of sEMG in clinical application is mainly relevant to the translation challenges between the clinical and research fields that can lead to a gap between the potential value of sEMG and its limited clinical applications (5). This may be the reason why the full potential of sEMG in clinical practice has not yet been realized. Some remarkable teaching initiatives have been implemented to understand and reduce this gap. For example, ISEK(International Society of Electrophysiology and Kinesiology) released a series of tutorials for clinicians (6). Additionally, a research topic has been recently carried out with the contribution of eighty authors (thirty-three engineers, sixteen medical doctors (MDs), eighteen physiotherapists (PTs), occupational therapists, and thirteen movement scientists) from seven countries (5). Within this research topic, research groups investigated the overall use of sEMG with perceptions of the benefits and barriers to using sEMG among potential practitioners (5,7- 9). Furthermore, novel hybrid educational models have been proposed in some countries to optimize diagnostic and treatment methods for healthcare professionals who provide technical and medical courses through interdisciplinary collaboration.

To add solution proposals to this existing project concerning the barriers, dissemination of research findings and education on sEMG are needed for its translation into practice. It is also needed to contribute some new information and the point of view from different countries for the identification of barriers to sEMG uptake and potential solutions. However, supporting information regarding the widespread use of sEMG is still unclear in many countries which can interact with factors such as socioeconomic status, educational systems, and ecosystems in clinical research. The barriers in clinical practice may include a lack of evidence for favorable outcomes, lack of consensus on its clinical utility, insufficient education or courses, and limited accessibility to EMG equipment. Therefore, we aimed to investigate the current use of sEMG, its advantages, facilitators, and barriers by using a survey among a variety of potential practitioners in Turkiye. Our motivation was to explore current trends, education, and clinical potential of sEMG and to offer a perspective how the widespread use of sEMG in clinics, research, and medical education models for further research.

METHODS

Study Design

The research design is a cross-sectional study conducted between November 15, 2020, and January 15, 2021. The study involved a multidisciplinary research team consisting of one MD from neurology, two MDs from physical medicine and rehabilitation (PM&R), one PT, one public health specialist, and one biomedical engineer. The online survey was developed based on a comprehensive review of the literature and input from experts in the field. It was designed to gather information on the current use of sEMG, perceived barriers and facilitators, and potential benefits. The survey included three sections with 46 items:

- Personal and work-related information.

- Factors affecting the adoption and application of sEMG.

- A 5-point Likert scale (1= strongly disagree, 5= strongly agree) assessing the potential benefits, barriers, and facilitating factors of sEMG.

Ethical approval for the study was obtained from Tarsus University Clinical Research Ethics Committee (date: 26/10/2020, no: 2020/44). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data Collection

The online survey conducted using Google Forms was accessible only in the Turkish language. We targeted potential sEMG practitioners in Turkiye, including Neurology MDs, PM&R MDs, Neurophysiologists, Kinesiologists, PTs, Sports Physicians, and other academic or research groups. We conducted a post hoc power analysis using G*Power 3.1 to determine the adequacy of our sample size for detecting significant differences in the use of sEMG among various professional groups. Based on an alpha level of 0.05, a medium effect size (Cohen's d = 0.5), and our total sample size of 104 participants, the power of the study was calculated. The power analysis revealed a power (1-β) of 0.80, which is generally considered acceptable for behavioral research. This suggests that our sample size is adequate to detect significant differences and draw valid conclusions

The Checklist for Reporting Results of Internet E-Surveys (CHERRIES) guidelines (see Appendix 1) was considered (10). The main page of the survey started with the informed consent form explicitly mentioning the aim of the study, the research team, survey response time, and how to fill it. We used the e-mail lists and social media channels of some organizations, including the Turkish Physiotherapists Association, the Turkish Neurology Association, and the PM&R Specialists Association. Also, we scanned literature through databases (Pubmed, Web of Science, Google Scholar) using the Mesh keyword "surface electromyography" to reach potential users of sEMG in Turkiye. Invitations were sent to 332 potential users via email lists and social media channels of relevant organizations. We periodically sent reminder emails and messages to participants for fourteen weeks. To avoid receiving multiple responses from the same respondent, only one response was allowed per email address. We guarantee to protect all data to be kept confidential to be only used for the present study. We received 107 responses, of which 104 were complete and included in the analysis.

The research was conducted in Turkey at the national level, involving the Turkish Physiotherapists Association, the Turkish Neurology Association, the Turkish Physical Medicine and Rehabilitation Specialist Physicians Association, the Physical Medicine and Rehabilitation and Neurology Departments of University Medical Faculties, Sports Sciences Departments and Undergraduate and Associate degree Physiotherapy Departments organizations and academic/research groups in Turkiye.

Statistical Analysis

We analyzed data using the SPSS 22.0 program (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). Initially, we reported descriptive statistics as counts, proportions, or percentages. We used cross-tabulations to analyze relationships between the professions of the participant and their educational backgrounds for EMG training. If the expected values for any cell in the cross-tabulation table were less than 5 and the sample size was small, Fisher's exact test was used to analyze the relationship between the variables due to the small expected cell frequencies (less than 5) and the small sample size. We then performed chi-square tests on nominal explanatory variables. The significance level was set as p and displayed response frequencies, means, and p values of the survey items in tabular and graphic formats.

RESULTS

Only completed questionnaires were analyzed. In total, we correctly received 104 surveys. The details of the participants' characteristics are given in Table 1.

Fig.1 shows the response rates of the participants in which areas they used sEMG. Each participant could choose one or more options from the list and answer open questions.

The response rates of participants for the questions are shown in Table 2, which are relevant to the current level of using sEMG, the barriers, and the facilitators for using sEMG.

Table 1. Characteristics of The Participants **(**Total Number of Participants=104)

Variable	Neurology& Clin Neurophysiol MDs N (%)	PM&R MDs N (%)	PTs N (%)	Non-clinicians N (%)	Total N (%
Gender					
Male	7 (6.7)	18 (17.3)	10 (9.6)	18 (17.3)	53 (50.9)
Female	5 (4.8)	29 (27.9)	16 (15.4)	1 (1.0)	51 (49.1)
Age					
20-30 years	1 (1.0)	8 (7.7)	11 (10.6)	1 (1.0)	21 (19.5)
31-40 years	5(4.8)	18 (17.3)	8 (7.7)	8 (7.7)	39 (37.8)
41-50 years	3 (2.9)	15 (14.4)	7 (6.7)	6(5.8)	31 (30.0)
> 51 years	3 (2.9)	6 (5.8)	0 (0.0)	4 (3.8)	13 (12.7)
Education					
Bachelor degree	0 (0.0)	1 (1.0)	12 (11.5)	1 (1.0)	14 (13.5)
Master's degree	0 (0.0)	5 (4.8)	6 (5.8)	3 (2.9)	14 (13.5)
Doctorate / Specialization degree	12 (11.5)	41 (39.4)	8 (7.7)	15 (14.4)	76 (73.0)
EMG Training					
None	2 (1.9)	17 (16.3)	14 (13.5)	12 (11.5)	45 (43.3)
nEMG course	8(7.7)	28 (26.9)	0 (0.0)	6 (5.8)	42 (40.4)
sEMG and nEMG course	0 (0.0)	2 (1.9)	3 (2.9)	0 (0.0)	5 (4.8)
Other	2 (1.9)	0 (0.0)	9 (75.0)	1 (1.0)	12 (11.5)
Working Condition					
Public (State)	4 (3.8)	13 (12.5)	5 (4.8)	4 (3.8)	26 (25.0)
Private	1 (1.0)	7 (28.0)	14 (56.0)	3 (2.9)	25 (24.0)
T&R Hospital	0 (0.0)	5 (4.8)	0 (0.0)	1 (1.0)	6 (5.8)
University	7 (5.8)	21 (20.2)	7 (6.7)	12 (11.5)	47 (45.2)

MDs=medical doctors, PM&R=physical medicine and rehabilitation, PTs=physiotherapists, Clin. Neurophy= clinical neurophysiology, T&R= training & researching, nEMG=needle EMG, N= number , %=percentage

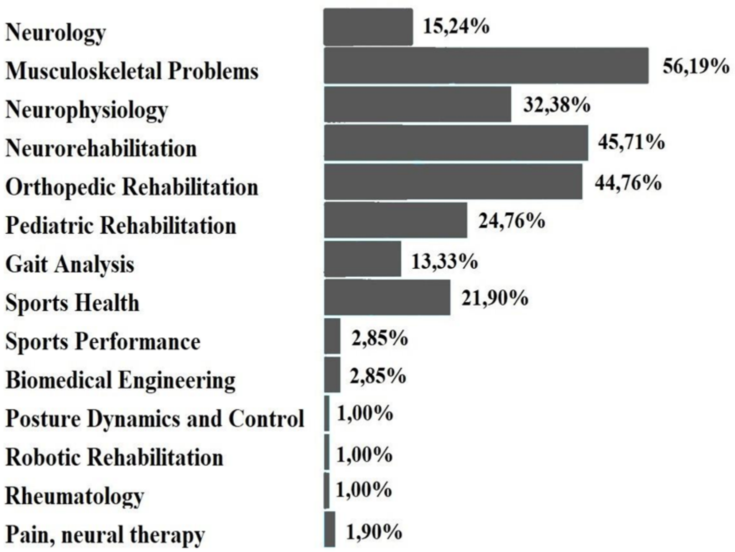

Fig. 1 Response rates of the participants in which areas they used sEMG (each participant chose one or more than one option.)

We mainly found overall perceptions of barriers as a lack of knowledge and experience about sEMG, data analysis, and interpretation of EMG signals. Table 3 shows the relationship between the participants' working fields and the variables "using sEMG in routine", "using sEMG for diagnostic", "using sEMG for treatment", and "using sEMG for research.

In Table 3, we found statistically significant differences between professions and using sEMG in their routine practice (p=0.001). Except for participants whose expertise is in neurology and neurophysiology, many of the participants reported they did not use sEMG in routine (Table 2). When comparing the difference between professions and purposes of using sEMG, we also found statistically significant differences for the diagnosis (p=0.002) and research (p=0.004) but no differences for treatment (p=0.103). Table 4 shows a cross-tabulation of participants' educational backgrounds on sEMG and those variables.

When comparing educational backgrounds and the barriers, we found statistically significant differences between the participants who did take the sEMG course and participants who did not (p=0.009). We also found a statistically significant difference between the variable participant's working fields and the variable "using sEMG in routine" (p0.05).

Table 2. Questions and Response Rates About The Current Level of Using sEMG, The Barriers Limiting The Use of sEMG, and The Facilitating and Encouraging Factors for The Use of sEMG

Questions	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
	N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**
The current use of sEMG					
I used sEMG during my undergraduate / graduate/ specialty or workplace training	32 (30.5)	13 (12.4)	8 (7.6)	17 (16.2)	34 (33.3)
I qualify for the sEMG application	39 (37.1)	16 (15.2)	12 (11.4)	18 (17.1)	19 (19.0)
I use the sEMG in my routine ractice	56 (54.3)	11 (10.5)	10 (9.5)	13 (12.4)	14 (13.3)
I use the sEMG for diagnostic	52 (49.5)	7 (7.6)	7 (7.6)	20 (19.0)	18 (17.1)
I use the sEMG for treatment.	57 (55.2)	16 (15.2)	13 (12.4)	11 (10.5)	7 (6.7)
I use the sEMG for prognostics	53 (50.5)	9 (9.5)	17 (16.2)	12 (11.4)	13 (12.4)
I use the sEMG for research.	46 (44.8)	9 (8.6)	5 (4.8)	20 (19.0)	24 (22.9)
The barriers limiting the use of sEMG					
Using sEMG is time-consuming	51 (48.6)	30 (29.5)	13 (12.4)	6 (5.7)	4 (3.8)
The most important limitation is the absence of sEMG device	13 (13.3)	8 (7.6)	28 (26.7)	28 (26.7)	27 (25.7)
The most important limitation is the high cost of the sEMG device and its components.	6 (5.7)	10 (9.5)	36 (34.3)	24 (22.9)	28 (26.7)
The most important limitation is a lack of knowledge and experience using sEMG	8 (7.6)	10 (10.5)	20 (19.0)	25 (23.8)	41 (39.0)
The most important limitation is a lack of knowledge of data analysis	9 (8.6)	17 (16.2)	31 (29.5)	30 (28.6)	18 (17.1)
The department or institution management does not support the use of sEMG	25 (23.8)	17 (17.1)	30 (28.6)	11 (10.5)	21 (20.0)
The facilitating and encouraging factors for the use of sEMG					
sEMG is useful in diagnosis.	13 (12.4)	3 (2.9)	20 (19.0)	27 (25.7)	41 (39.0)
sEMG is useful in treatment.	14 (13.3)	6 (5.7)	35 (33.3)	30 (28.6)	19 (18.1)
sEMG methods are reliable.	7 (7.6%)	4 (3.8)	22 (21.0)	41 (39.0)	30 (28.6)
sEMG methods are reproducible.	5 (4.8)	4 (3.8)	11 (10.5)	39 (37.1)	45 (42.9)
I will use sEMG much more in the future.	7 (7.6)	4 (3.8)	17 (16.2)	29 (27.6)	47 (44.8)
The experience in needle EMG is facilitating in sEMG.	4 (3.8)	4 (3.8)	15 (14.3)	32 (30.5)	50 (47.6)
Using sEMG in diagnosis and treatment increases patient satisfaction.	3 (2.9)	6 (5.7)	33 (31.4)	26 (25.7)	36 (34.3)

N= number

Table 3. The Relationship Between Participants' Expertise Fields and The Response to The Current Status and Purpose of Using sEMG

Working Field	Strongly Disagree N(%)	Disagree N(%)	Neutral N(%)	Agree N(%)	Strongly Agree N(%)	Chi-square test p
Question: I use sEMG in my routine practice						
Neurology & Clin Neurophysiol MDs	3 (25.0)	1 (8.3)	1 (8.3)	6 (50.0)	1 (8.3)	**0.001*** [a]
PM&R MDs	22 (46.8)	8 (17.0)	5 (10.6)	5 (10.6)	7 (14.)	
PTs	23 (88.5)	0 (0.0)	1 (3.8)	1 (3.8)	1 (3.8)	
Non-clinicians	8 (42.1)	2 (10.5)	3 (15.8)	1 (5.3)	5 (26.3)	
Total	56 (53.8)	11 (10.6)	10 (9.6)	13 (12.5)	14 (13.5)	
Question: I use sEMG for diagnostic purposes						
Neurology & Clin Neurophysiol MDs	3 (25.)	1 (8.3)	1 (8.3)	4 (33.3)	3 (25.0)	**0.002***[a]
PM&R MDs	16 (34.0)	5 (10.6)	2 (4.3)	12 (25.5)	2 (25.5)	
PTs	22 (84.6)	1 (3.8)	1 (3.8)	1 (3.8)	1 (3.8)	
Total	52 (50.0)	7 (6.7)	7 (6.7)	20 (19.2)	18 (17.3)	
Question: I use the sEMG for treatment purposes						
Neurology & Clin Neurophysiol MDs	8 (66.7)	4 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0.103[a]
PM&R MDs	20 (42.6)	10 (21.3)	6 (12.8)	7 (14.9)	4 (8.5)	
PTs	18 (69.2)	2 (7.7)	2 (7.7)	2 (7.7)	2 (7.7)	
Total	57 (54.8)	16 (15.4)	13 (12.5)	11 (10.6)	7 (6.7)	
Question: I use sEMG for research purposes						
Neurology & Clin Neurophysiol MDs	3 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**0.004***[a]
PM&R MDs	21 (44.7)	7 (14.9)	1 (2.1)	10 (21.3)	8 (17.0)	
PTs	17 (65.4)	1 (3.8)	3 (11.5)	2 (7.7)	3 (11.5)	
Non-clinicians	5 (26.3)	1 (5.3)	1 (5.3)	2 (10.5)	10 (52.6)	
Total	46 (44.2)	9 (8.7)	5 (4.8)	20 (19.2)	24 (23.1)	

MDs=medical doctors, PM&R=physical medicine and rehabilitation, PTs=physiotherapists, Clin. Neurophysiol= clinical neurophysiology; N= number, %=percentage within each working field, p= statistically significant level, * = $p < 0.05$ Fisher's exact test was used to analyze the relationship between the variables due to the small expected cell frequencies (less than 5)

DISCUSSION

Current Level of Using sEMG

Our study revealed that sEMG is underutilized in clinical practice, particularly for prognosis and treatment, with significant differences in usage among various professional groups. In Table 3. Furthermore, most of the neurology, clinical neurophysiology, and PM&R MDs used sEMG for diagnosis, but PTs and non-clinicians did not. Besides, while most non-clinicians agreed with the research, clinicians and PTs did not. This finding aligns with previous studies indicating that sEMG is more relevant for research than clinical practice (8,9). In other words, sEMG is commonly used for research purposes rather than for routine clinical practice. Most PTs surprisingly agreed on using sEMG neither for treatment nor research. One reason for these results can be relevant to the position of PTs. In Turkiye, PTs generally works in cooperation with MDs who are specialist in the diagnosis of diseases and the other members of the rehabilitation team. They inform the relevant specialist physician about the course of the treatment. PTs showed the lowest percentage of using sEMG in their routine clinical practice (agree=3,8% and strongly agree=3,8%) when comparing the other practitioners. In terms of perception and attitudes, participants might have probably believed that sEMG has been a part of the competence fields of neurology rather than physiotherapy or rehabilitation. Previous studies reported compatible results (7-9). This result may be the case in many other countries, and this point

Table 4. Cross-tabulation of Participants' Educational Backgrounds on sEMG and The Questions Relevant to The Barriers Limiting The Use of sEMG and The Facilitators

sEMG Training	Strongly Disagree N (%)	Disagree N (%)	Neutral N (%)	Agree N (%)	Strongly Agree N (%)	Chi-square test p
Question: The most important limitation in using sEMG is the lack of knowledge and experience						
Yes	2 (4.3)	7 (15.2)	8 (17.4)	17 (37.0)	12 (26.1)	
No	6 (10.3)	3 (5.2)	12 (20.7)	8 (13.8)	29 (50.0)	**0.009*ᵃ**
Total	8 (7.7)	10 (9.6)	20 (19.2)	25 (24.0)	41 (39.4)	
Question: Using sEMG is time-consuming						
Yes	22 (47.8)	15 (32.6)	4 (8.7)	4 (8.7)	1 (2.2)	
No	29 (50.0)	15 (25.9)	9 (15.5)	2 (3.4)	3 (5.2)	0.554ᵃ
Total	51 (49.0)	30 (28.8)	13 (12.5)	6 (5.8)	4 (3.8)	
Question: The most important limitation in using sEMG is the lack of knowledge and experience in data analysis						
Yes	3 (6.5)	8 (17.4)	14 (30.4)	16 (34.8)	5 (10.9)	
No	5 (8.6)	9 (15.5)	17 (29.3)	14 (24.1)	13 (22.4)	0.529ᵃ
Total	8 (7.7)	17 (16.3)	31 (29.8)	30 (28.8)	18 (17.3)	
Question: sEMG will be used much more in the future						
Yes	4 (8.7)	3 (6.5)	8 (17.4)	12 (26.1)	19 (41.3)	
No	3 (5.2)	1 (1.7)	9 (15.5)	17 (29.3)	28 (48.3)	0.680 ᵃ
Total	7 (6.7)	4 (3.8)	17 (16.3)	29 (27.9)	47 (45.2)	
Question: Getting experience in needle EMG is facilitating sEMG						
Yes	1 (2.2)	2 (4.3)	3 (6.5)	18 (39.1)	22 (47.8)	
No	3 (5.2)	1 (1.7)	12 (20.7)	14 (24.1)	28 (48.3)	0.134 ᵃ
Total	4 (3.8)	3 (2.9)	15 (14.4)	32 (30.8)	50 (48.1)	
Question: Using sEMG in diagnosis and treatment increases patient satisfaction						
Yes	0 (0.0)	3 (6.5)	10 (21.7)	13 (28.3)	20 (43.5)	
No	3 (5.2)	3 (5.2)	23 (39.7)	13 (22.4)	16 (27.6)	0.122 ᵃ
Total	3 (2.9)	6 (5.8)	33 (31.7)	26 (25.0)	36 (34.6)	

N= number, %=percentage within each working field, p= statistically significant level, * = $p < 0.05$ Fisher's exact test was used to analyze the relationship between the variables due to the small expected cell frequencies (less than 5), Yes= participants who took sEMG course, No: participants who did not take sEMG course

should be considered (8,9). PTs probably don't perform gait or movement analysis, and therefore, they do not need sEMG. Whereas, PTs are mainly expected to use a wide range of assessments, including aerobic capacity/endurance, anthropometric measurements, cognitive status, circulation, respiration, cranial and peripheral nerve integrity, gait, balance and locomotion, skin integrity, joint integrity and mobility, motor function, muscle performance, neuro-motor development and supportive device, orthosis, prosthesis, protective and supportive device, pain, posture, reflexes, range of motion, and sensory integrity assessments. This may be because the lack of knowledge and awareness of PTs during educational and clinical experiences leads to a limited translational effort from research outcomes to clinical practice (3,11). Gofredo et al. reported that the insufficient knowledge of sEMG among PTs was the reason for the limited diffusion of sEMG in the rehabilitation hospital (8). Our results also showed that PTs declared a great interest and a very positive approach to rehabilitation technologies but they didn't attend either for a longer course of studies (e.g. 4 years in the USA, 3 years in most Europen Countries) or a clinical doctorate (as in the USA) or Ph.D. (as in many countries, including the USA). This finding may be addressed as contradictory behavior. The limited use among PTs and clinicians suggests a need for enhanced training and education in sEMG applications. Therefore, in undergraduate and graduate education programs of PTs, courses on sEMG should be supported because the test and measurement skills are an indispensable part of the EBP approach (12). We present two perspectives to find possible solutions. First is the transformation of attitudes and perceptions related to the use of sEMG among clinicians. Second, is translating advances in sEMG into medical education curriculums and clinical settings. Although sEMG has many applications in the treatment and rehabilitation of patients (2,13,14), our results also revealed that there was no sufficient translation into clinical practice for treatment. sEMG has not been included in the core medical education programs although it has been used in a few centers among the specialist training programs while routine needle EMG has been included in specialization training programs (neurology, clinical neurophysiology, and PM&R) in Turkiye. Therefore, interdisciplinary collaboration and hybrid educational models can give effective solutions to meet the demands and increase clinical acceptance among the clinician community (15).

Barriers Limiting to Use of sEMG

In the present study, the main barriers identified were a lack of knowledge and experience with sEMG, high costs of devices, and limited institutional support. These barriers are consistent with those reported in the literature and highlight the need for targeted educational interventions and investment in affordable sEMG technology (3-5,7, 15-17). However, the majority of participants reported that using sEMG did not cause time-consuming work in our study contrary to previous studies (7,9). Regarding financial issues, the high cost of EMG devices could be an obstacle to the widespread use of sEMG due to the limited market and the high exchange rate in some countries such as Turkiye. Furthermore, health insurance does not pay for evaluations made with sEMG in many countries. This situation stands as a barrier to functional evaluation and measurements of sEMG. We expect that new technical and technological advances in sEMG will contribute to low-cost devices and software. Concerning organization obstacles, our results showed that approximately one-third of respondents (30,5%) stated that the management department did not provide sEMG courses or devices. It may relate the reason for this to the percentage (26.7%) of participants who work in the private sector. The lower use of sEMG in private clinics may be due to not considering it as a mandatory process in the assessment protocol. In addition, sEMG examinations (as in gait analysis) may interfere with efficient patient flow and insurance services. In Turkiye, it is a fact that private institutions focus on the treatment rather than the assessments of the outcomes. This may be because the clinical research studies are especially supported in university and education&research hospitals in which approximately half of the participants worked. The organizations should support clinicians with special training, sufficient administrative support, and adequate devices for widespread clinical acceptance.

We also found statistical differences relevant to educational backgrounds and the lack of knowledge and experience using sEMG systems. Our results showed that educational backgrounds about sEMG make adaptation easier for clinicians in their routine clinical practice. While clinicians receive education in other diagnostic modalities like ECG and EEG, sEMG training can be often limited or not included in their formal education curriculum. The absence of dedicated training programs could lead to a knowledge gap and a lack of confidence in integrating sEMG into clinical practice. Integrating sEMG education and training into the formal curriculum for healthcare professionals, such as physicians, physical therapists, and occupational therapists, could be essential. Comprehensive training initiatives encompassing dedicated programs, workshops, and continuing education courses can enhance clinicians' familiarity with sEMG, covering topics such as electrode placement, signal analysis, interpretation, and clinical applications. Hands-on practical training should be emphasized to improve clinicians' confidence and proficiency in utilizing sEMG. Therefore, multidisciplinary bachelor's and master's programs are needed because advances in medical technology need new professional skills with medical and technical knowledge that bridge the gap between innovative technology and clinical practice. Recently, these types of new hybrid models have been applied in Dutch Education, by existing technology in innovative ways to optimize diagnostic and treatment methods. For example, The Clinical Technology degree program comprises technology courses and medical courses through a collaborative partnership between the Delft University of Technology and the Techmed Centre of Twente University in Dutch (18,19). This type of hybrid program can provide students to analyze the human body and diseases from the perspective of an engineer and learn to work with complex technologies through collaboration with industry and hospitals on the development of new solutions for healthcare. Promoting collaboration between researchers, clinicians, and educators including clinical and engineering can bridge the gap between research findings and clinical practice. Researchers can work closely with clinicians to identify and address specific clinical needs, develop relevant research studies, and provide evidence for the clinical utility of sEMG. Clinicians can contribute their expertise in patient assessment and treatment planning, ensuring that research outcomes align with real-world clinical scenarios. Educators can play a crucial role in incorporating sEMG into medical and allied health curricula, promoting interdisciplinary approaches that encourage integration and utilization of sEMG in clinical practice. Efforts should be made to make sEMG technology more accessible and affordable. This includes developing cost-effective sEMG systems and ensuring their availability in different healthcare settings. Collaborations between industry and academia can drive technological advancements, making sEMG devices more user-friendly, portable, and affordable for clinicians.

In addition, the EBP approach in education and training should be planned in line with national and international accreditation criteria because EBP is an important approach for students to access, evaluate, and apply research evidence in clinical decision-making (12). Conducting robust clinical studies to generate evidence for the clinical utility and effectiveness of sEMG is vital. Well-designed research studies, including randomized controlled trials and systematic reviews, can provide high-quality evidence supporting the use of sEMG in specific clinical applications. This evidence could be disseminated to the medical community through peer-reviewed publications and conferences to increase awareness and confidence in sEMG among clinicians One major barrier was also the correct analyses and interpretation of sEMG signals because there is a lack of specialized courses on sEMG in the curriculums. Interpreting sEMG signals requires expertise and experience. The complexity of differentiating between muscle activation patterns, understanding the underlying neuromuscular mechanisms, and distinguishing between normal and abnormal muscle activity poses challenges for clinicians. The interpretation of sEMG data may require specialized knowledge, which can act as a deterrent to its widespread use in clinical settings. To promote this point, new teaching content and materials that can meet the knowledge and skill needs of potential practitioners in sEMG can be adopted (20,21). For example, teaching initiatives (a series of tutorials for clinicians) organized by ISEK can be given as one of the good examples (6, 22). These tutorials and webinars have been oriented to non-engineers to provide technical backgrounds on some fundamental topics in sEMG such as not only anatomy from the perspective of medicine but also the body from the perspective of the laws of biomechanics or fundamentals of electrophysiological signals. Thus, novel hybrid curriculums for clinicians and PTs can provide a comprehensive overview of the technical aspects of recording and analyzing sEMG signals. However, integrating the technological and methodological advances into the existing sEMG systems cannot be simultaneous (9). Therefore, further continuous efforts would be needed to develop courses on novel methods for clinicians. The user-friendly software and hardware for analysis and interpretation of sEMG signals could also play a key facilitator role in helping clinicians to provide use of sEMG in clinics throughout the practical experience. Providing ongoing support and resources to clinicians during the implementation phase is crucial. This can include mentorship programs, online forums, and dedicated support networks where clinicians can seek guidance, share experiences, and learn from experts in the field. Clinicians should also have access to comprehensive software tools for data analysis and interpretation to facilitate the integration of sEMG into their clinical workflow.

Facilitators and Benefits of Using sEMG

In general, our results indicated that participants recognized the potential benefits of sEMG in diagnosis and treatment, including increased patient satisfaction and improved clinical outcomes. The participants had a common perception of the clinical potential of sEMG to provide reliable and reproducible application in clinical practice, similar to previous studies (8,9,14). These perceptions suggest that with adequate training and resources, the clinical adoption of sEMG could be significantly enhanced. Participants may have expected that the potential benefits of sEMG could increase patients' satisfaction and improve tracking of the patient's progress, specific quantitative evidence, and clinical information. Of course, the knowledge and experience about sEMG may also affect aspects related to patient management. Giving information to the patients about the advantages of sEMG may decrease stress and may positively change patients' satisfaction. The patient information on sEMG could be very important to improve patient satisfaction and EBP-based health care (23). In Table 4, all participants with different educational backgrounds for sEMG had positive beliefs and attitudes towards the use of sEMG. Our results show that participants widely agreed on the fact that experiences with needle EMG can be a facilitator for sEMG. By implementing the strategies abovementioned such as comprehensive training and education, interdisciplinary collaboration, technology accessibility and affordability, and providing ongoing support and resources, the widespread use of sEMG in clinical practice can be facilitated. These strategies can also promote the integration of sEMG as a valuable tool for diagnostic, treatment, and monitoring purposes in various clinical settings.

Limitations

This study had some potential limitations. Although this study attempted to include a variety of participants from diverse professional settings, these data did not represent perceptions across the wider potential practitioners of sEMG fields in Turkiye because potential participants were less willing to respond to such a survey study. This may be considered as nonresponse bias, which is related to the decision to take part in our study and the differences between those who cooperated and those from whom data were not gathered. Similarly, the present study had a small sample size for analysis with cross tables, which did not represent any "working field" as a "national" representation. We, therefore, used the chi-square test to a limited extent to investigate how the correlation of results differs according to participant's expertise fields and being sEMG training before.

Conclusion : Our study provides valuable insights into the current utilization, barriers, and facilitators of sEMG among clinicians in Türkiye. Despite positive perceptions, significant barriers limit its widespread adoption. Overcoming these challenges through educational and technological advancements is essential for enhancing its clinical utility. We recommend integrating sEMG training into medical and allied health curricula, developing multidisciplinary educational programs, and fostering collaborative research. Additionally, hybrid education models, such as the Dutch model, are necessary to equip professionals with both medical and technical expertise.

The statement of conflict of interest : The authors declare that there are no conflicts of interest

Author Contributions: Concept: VA; Design Planning the methods to generate hypothesis: VA; Supervision: MZ, HU; Data Collection and/or Processing: VA, MZ, AK, HU, ED; Data Analysis and/or Interpretation: VA, HT; Literature Search: VA, MZ, AK; Writing Manuscript: VA, MZ, AK, HT, ED.

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Appendix

CHERRIES Check List

Checklist for Reporting Results of Internet E-Surveys (CHERRIES)

Checklist Item	Explanation	Page Number
Describe survey design	Describe the target population and sample frame. Is the sample a convenience sample? (In "open" surveys this is most likely.)	Page=3, Method Section
IRB approval	Mention whether the study has been approved by an IRB.	Page=3, Method Section
Informed consent	Describe the informed consent process. Where were the participants told the length of time of the survey, which data were stored and where and for how long, who the investigator was, and the purpose of the study?	Page=3, Method Section
Data protection	If any personal information was collected or stored, describe what mechanisms were used to protect unauthorized access.	Page=4, Method Section: Guaranteed with user name and password of the responsible researchers' login to Google Form
Development and testing	State how the survey was developed, including whether the usability and technical functionality of the electronic questionnaire had been tested before fielding the questionnaire.	Page=3, Method Section.
Open survey versus closed survey	An "open survey" is a survey open for each visitor of a site, while a closed survey is only open to a sample that the investigator knows (password-protected survey).	Open survey
Contact mode	Indicate whether or not the initial contact with the potential participants was made on the Internet. (Investigators may also send out questionnaires by mail and allow for Web-based data entry.)	Page=3 and 4, Method Section: The potential participants were contacted with mail list and web-based data. Questionnaires were sent out by mail
Advertising the survey	How/where was the survey announced or advertised? Some examples are offline media (newspapers), or online (mailing lists – If yes, which ones?) or banner ads (Where were these banner ads posted and what did they look like?). It is important to know the wording of the announcement as it will heavily influence who chooses to participate. Ideally, the survey announcement should be published as an appendix.	Page=3 and 4, Method section: The Survey was announced through online mailing lists.
Web/E-mail	State the type of e-survey (eg, one posted on a Web site, or one sent out through e-mail). If it is an e-mail survey, were the responses entered manually into a database, or was there an automatic method for capturing responses?	Page=3, Methods section: a web-based survey
Context	Describe the Web site (for mailing list/newsgroup) on which the survey was posted. What is the Website about, who is visiting it, what are visitors normally looking for? Discuss to what degree the content of the Web site could pre-select the sample or influence the results. For example, a survey about vaccination on an anti-immunization Web site will have different results from a Web survey conducted on a government Web site	Page=3, Method Section: the online survey was developed using the Google Form.
Mandatory/voluntary	Was it a mandatory survey to be filled in by every visitor who wanted to enter the Web site, or was it a voluntary survey?	Page=3, Method Section: It was voluntary.
Incentives	Were any incentives offered (eg, monetary, prizes, or non-monetary incentives such as an offer to provide the survey results)?	None
Time/Date	In what timeframe were the data collected?	Page=4, Methods section: 14 weeks
Randomization of items or questionnaires	To prevent biases items can be randomized or alternated.	No
Adaptive questioning	Use adaptive questioning (certain items, or only conditionally displayed based on responses to other items) to reduce the number and complexity of the questions.	Methods and Results section: yes
Number of Items	What was the number of questionnaire items per page? The number of items is an important factor in the completion rate.	46(maximum)
Number of screens (pages)	Over how many pages was the questionnaire distributed? The number of items is an important factor in the completion rate.	4 (maximum)
Completeness check	It is technically possible to do consistency or completeness checks before the questionnaire is submitted. Was this done, and if "yes", how (usually JAVAScript)? An alternative is to check for completeness after the questionnaire has been submitted (and highlight mandatory items). If this has been done, it should be reported. All items should provide a non-response option such as "not applicable" or "rather not say", and the selection of one response option should be enforced.	Answers to all questions were voluntary, and we included no completeness checks during the survey.

Review step	State whether respondents were able to review and change their answers (e.g., through a Back button or a Review step which displays a summary of the responses and asks the respondents if they are correct).	"Go back" and "proceed/next" buttons were used so that participants could switch between pages and change their answers
Unique site visitor	If you provide view rates or participation rates, you need to define how you determine a unique visitor. There are different techniques available, based on IP addresses cookies, or both.	Each participant was able to fill out the survey with their user name and individual mail address. Only participants completing all sections were identified as respondents. We therefore calculated the participation rate
View rate (Ratio of unique survey visitors/unique site visitors)	Requires counting unique visitors to the first page of the survey, divided by the number of unique site visitors (not page views!). It is not unusual to have view rates of less than 0.1 % if the survey is voluntary.	
Participation rate (Ratio of unique visitors who agreed to participate/unique first survey page visitors)	Count the unique number of people who filled in the first survey page (or agreed to participate, for example by checking a checkbox), divided by visitors who visit the first page of the survey (or the informed consent page, if present). This can also be called the "recruitment" rate.	
Completion rate (Ratio of users who finished the survey/users who agreed to participate)	The number of people submitting the last questionnaire page is divided by the number of people who agreed to participate (or submitted the first survey page). This is only relevant if there is a separate "informed consent" page or if the survey goes over several pages. This is a measure of attrition. Note that "completion" can involve leaving questionnaire items blank. This is not a measure of how completely questionnaires were filled in. (If you need a measure for this, use the word "completeness rate".)	Page=4, Method and Results section:
Cookies used	Indicate whether cookies were used to assign a unique user identifier to each client computer. If so, mention the page on which the cookie was set and read, and how long the cookie was valid. Were duplicate entries avoided by preventing users access to the survey twice; or were duplicate database entries having the same user ID eliminated before analysis? In the latter case, which entries were kept for analysis (e.g., the first entry or the most recent)?	A total of 107 participants of 332 potential users sent invitations and agreed to respond to the survey. And total participants included in the present study.
IP check	Indicate whether the IP address of the client computer was used to identify potential duplicate entries from the same user. If so, mention the period for which no two entries from the same IP address were allowed (e.g., 24 hours). Were duplicate entries avoided by preventing users with the same IP address access to the survey twice; or were duplicate database entries having the same IP address within a given period eliminated before analysis? If the latter, which entries were kept for analysis (e.g., the first entry or the most recent)?	Page 4, Method Section: To avoid receiving multiple responses from the same respondent, only one response was allowed per email address
Log file analysis	Indicate whether other techniques to analyze the log file for identification of multiple entries were used. If so, please describe.	None
Registration	In "closed" (non-open) surveys, users need to log in first and it is easier to prevent duplicate entries from the same user. Describe how this was done. For example, was the survey never displayed a second time once the user had filled it in, or was the username stored together with the survey results and later eliminated? If the latter, which entries were kept for analysis (e.g., the first entry or the most recent)?	No login was required.
Handling of incomplete questionnaires	Were only completed questionnaires analyzed? Were questionnaires that terminated early (where, for example, users did not go through all questionnaire pages) also analyzed?	Page 4, Results Section: Only completed questionnaires were analyzed.
Questionnaires submitted with an atypical timestamp	Some investigators may measure the time people needed to fill in a questionnaire and exclude questionnaires that were submitted too soon. Specify the timeframe that was used as a cut-off point, and describe how this point was determined.	
Statistical correction	Indicate whether any methods such as weighting of items or propensity scores have been used to adjust for the non-representative sample; if so, please describe the methods.	No statistical correction was implemented

This checklist has been modified from Eysenbach G. Improving the quality of Web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES). J Med Internet Res. 2004 Sep 29;6(3):e34 (erratum in J Med Internet Res. 2012; 14(1): e8.). Article available at https://www.jmir.org/2004/3/e34/; erratum available https://www.jmir.org/2012/1/e8/. Copyright ©Gunther Eysenbach. Originally published in the Journal of Medical Internet Research, 29.9.2004 and 04.01.2012.