International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 13; Issue: 11; November 2026
Website: www.ijrrjournal.com
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Sleeve vs. Cuff Suspension: Effect on Stride Parameter and Energy Expenditure in Unilateral Transtibial Patella Tendon Bearing Prosthesis Users

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DOI: https://doi.org/10.52403/ijrr.20261113

ABSTRACT

The suspension systems influence the energy expenditure and stride parameters of a transtibial amputee. Stride characteristics and energy expenditure were studied with the use of both cuff and sleeve suspension in 30 unilateral transtibial patella tendon bearing prosthesis users. A post test only control group design was followed. The aim of the study is to check the efficiency of both these commonly prescribed suspension units on the basis of their effect on stride parameters and energy expenditure. A pair t-test analysis was used to compare the difference between cuff and sleeve suspension in terms of stride parameters and energy expenditure. The mean age of the population taken is 32.8 ± 6.53 years. By comparing the both suspension systems, the results shown that there will be significant difference between cuff and sleeve suspension in stride length (p=.000, t=-5.482), in step length (p=.000, t=-5.908), in velocity (p=.000, t=-11.667) and in energy expenditure (p=.000, t=-6.536) while no significant difference is observed with respect to cadence. These findings of the study suggest that the use of sleeve suspension in unilateral patella tendon bearing prosthesis is significantly more beneficial than cuff suspension over stride characteristics and energy expenditure

Keywords: PTB prosthesis, suspension, stride parameter, energy expenditure.

INTRODUCTION

Amputation is the surgical removal of the limb through a part of the bone. It is one of the most cruel and destructive procedure to be done in order to save the patient's life [1]. Amputations are performed at various levels. After the amputation rehabilitative interventions are followed to reconstruct the amputees self believe and to provide a healthy way to live in the social context.

In rehabilitation pathway the prosthetic intervention plays a vital role. A successful prosthetic fitting add new wings to the life of an amputee. In a prosthetic fitment many components play effective role on the success of the prosthesis. Prosthesis consists of socket, shank piece or pylon and feet. The socket provides space and contour in which the residual limb fits. The suspension system is used to secure the prosthesis on the residual limb. The suspension system is

one of the most vital components that relates to patient's security and comfortability need. Selection of the optimal suspension is paramount to achieving safe and efficient prosthetic ambulation. Any improper selection of suspension system leads to discomfort, asymmetry in gait, and pistoning of the prosthesis thus results in more energy expenditure [2].

In lower limb amputations transtibial amputation is the twice common than the transfemoral [3]. In a transtibial amputation various design options are available like patella tendon bearing design, total surface bearing design etc. In patella tendon bearing there will be increased contact or weight bearing over patella tendon area, inferior to patella and avoid pressure from the weight sensitive areas of the residual limb. In PTB prosthesis various types of suspension systems are incorporated eg: supracondylar cuff suspension, sleeve suspension, shuttle pin suction suspension etc.

The supracondylar cuff suspension consists of an adjustable strap encircling the distal thigh above the femoral condyles. The strap retains the prosthesis over the residual limb by forming a proper grip over both the femoral condyles [4]. The cuff suspension is a long standing suspension option with some negative issues like restriction in sitting, does not provide maximum M-L stability and poor cosmesis.

Sleeves are made of latex, neoprene, silicone etc. sleeves fit snugly over the proximal aspect of the prosthesis and are rolled up over the patient's thigh 2 or 3 inch proximal to the prosthetic socks. By making contact with the patient's skin, the sleeve converts the socket into a sealed chamber[4]. In sleeve suspension if the socket starts to displace distally on the leg, a partial vacuum is created inside the socket and atmospheric pressure holds the socket securely in contact with the skin.

Though both the suspensions are prescribed in case of patella tendon bearing prosthesis users but there will be no clear evidence about the prescription criteria with relation to the efficiency of the suspension system. The efficiency of a suspension system depends on several factors: the effect on gait pattern, the energy expenditure.

The effect of a suspension system on gait pattern can be quantified by analyzing the stride characteristics. The normal stride characteristic includes cadence, velocity, step length and stride length.

To analyze the stride characteristics 10m paper walkway test is a convenient & valid instrument. So in this study this method is used to check the effect on stride characteristics [6].

The energy expenditure also plays a vital role in checking the efficiency of a suspension system [7]. It is the amount of energy utilized during ambulation by the amputee.

The PCI (physiological cost index) measurement is the simple method to measure the energy cost. It is measured by measuring the heart rate [8]. The formula is {walking heart rate(b/m)-resting heart rate(b/m)}/walking speed(meter/minute). In previous studies the effect of cuff suspension and sleeve suspension on gait characteristics and energy expenditure is not properly quantified. This study is focused on Indian population so it took the most commonly prescribed suspension systems in account to check their efficiency in terms of stride parameters & energy expenditure.

METHODS

The subjects would be invited to participate in the study. According to the inclusion criteria the subjects would be assessed & screened. Subject consenting to participate in the study signed the consent form. The detailed information would be given to the subjects about the procedure all the subjects had been wearing prosthesis for at least six months.

The Stride characteristics would be calculated by using Paper walkway & stop watch. The 10 meter walkway will be used in which initial & last 2 meter will be marked for acceleration & deceleration. To calculate the resting heart rate, the subject

would be given rest for ½ hour to bring the subject in resting position.

Before the stride parameter would be collected, the resting heart rate would be measured in the resting position. After collecting the stride parameters, the patient would be asked to walk for 6 minutes and at the end of 6 minutes the walking heart rate would be measured by pulse oxymeter in sitting position.

STRIDE CHARACTERISTICS

Stride characteristics are the parameters which show the walking efficiency of a person. The normal stride characteristics include stride length, step length, cadence and velocity. There are so many methods to measure the stride parameters. Paper walkway is one of them. The 10 meter paper walkway was used in this study, in which middle 6 meter was considered for the estimation of the stride characteristics. The initial & last 2meter was marked for acceleration & deceleration. The patient was fitted with patella tendon bearing prosthesis with cuff suspension. The subject's gait symmetry was assessed using observational method. After gait symmetry analysis, the socks were pulled over the shoe on the prosthetic as well as in normal side. At the planter aspect of the shoe ink was applied over the pulled socks to get the foot print of the subject. Then subject was made stand on the floor. The subject instructed that on the word "Go" he should on the paper walkway. When the subject crosses the initial line of acceleration, immediately the stop watch was started to get the time & when the subject touches the line of deceleration the stop watch was stopped. The stride data were calculated within the 6 meter. After this the subject is fitted with the PTB prosthesis with neoprene sleeve suspension for one week (one week is given as adaptation period). after one week the stride characteristics and energy expenditure of the subject is evaluated.

PHYSIOLOGICAL COST INDEX

The energy expenditure can be measured by various methods like by measuring the O2 cost or by PCI. The measurement of O2 cost is very cumbersome. The PCI measurement is the simple method to measure the energy cost. It is measured by measuring the heart rate. the formula is{walking heart rate(b/m)-resting heart rate(b/m)}/walking speed (meter/minute). For the measurement of resting heart rate, initially the subject was given rest for ½ hour to bring the subject in resting position. And before collecting the stride parameters the resting heart was measured. After stride data collection, the patient was asked to walk for 6 minutes & at the end of 6 minute the walking heart rate was measured by pulse oxymeter.

Each subject has existing transtibial definitive patella tendon bearing prosthesis with cuff suspension. All had been wearing prosthesis for at least six months. None of the subject had residual limb pain, swelling or neuroma and non exhibited major gait deviation. Residual limb for all subjects was at least 30%of total sound length, but did not exceeded more than 52% i.e. 15%of total body height. These criteria reflect the importance of maintaining the consistent limb length among subjects when evaluating stride parameters and energy cost.

RESULTS

A sample of 30 persons with unilateral transtibial amputation took part in this study. In which 29 male unilateral transtibial & 1 female transtibial amputee participated. A paired t-test was used to compare the difference between cuff suspension and sleeve suspension in terms of stride characteristics and energy expenditure.

The mean age of male amputee was 37.10±7.37& of female was 43 years & for entire population the mean age was 32.8±6.53. The mean of stump % of male subject with transtibial amputees was 40.90±3.89 and for female was 48.91% & for entire population 41.17±4.09% & the mean of BMI for male subjects was

23.27±2.34 and for female was 21.20 & for entire population was 23.20±2.33 (Table A).

Stride characteristics

The result of stride characteristics between the cuff suspension and sleeve suspension revealed significant difference in stride length (t-value= -5.842, p=.000) (fig. A), step length (t-value= -5.908, p=0.000) (fig. B) and velocity (t-value= -11.667, p=0.000) (fig. C). In Cadence (t-value= -2.039, p=0.051) (fig. D) there was no significant difference found.

PHYSIOLOGICAL COST INDEX

There was significant difference seen in Energy expenditure (t-value= 6.536, p= 0.000) (fig. E), using cuff suspension or sleeve suspension in unilateral transtibial Patella tendon bearing prosthesis users. Sleeve suspension consumes less amount of energy during walking.

Table-A: Descriptive Statistics

PROFILE	N	SEX	MEAN	SD
AGE	29	Male	37.10	7.37
	1	Female	43.00	
	30	Total	37.30	7.33
HEIGHT	29	Male	167.22	7.96
	1	Female	152.00	
	30	Total	166.71	8.30
WEIGHT	29	Male	65.00	7.32
	1	Female	49.00	
	30	Total	64.47	7.77
STUMP LENGTH	29	Male	40.90	3.89
	1	Female	48.91	
	30	Total	41.17	4.09
BMI	29	Male	23.27	2.34
	1	Female	21.20	
	30	Total	23.20	2.33

Age – years Weight - Kilograms
Height – Centimeters Stump Length- Percentage

Table-B: - Comparison of Stride length: Cuff suspension vs. Sleeve suspension (N=30)
Paired samples t-test between STRDC-STRDS

STRIDE LENGTH	Mean ±SD	t-value	p-value
STRDC	109.28±14.97	-5.842**	.000
STRDS	118.11±14.60		
**-Significant at 0.05 level			

STRDC – STRIDE LENGTH WITH CUFF SUSPENSION
STRDS – STRIDE LENGTH WITH SLEEVE SUSPENSION

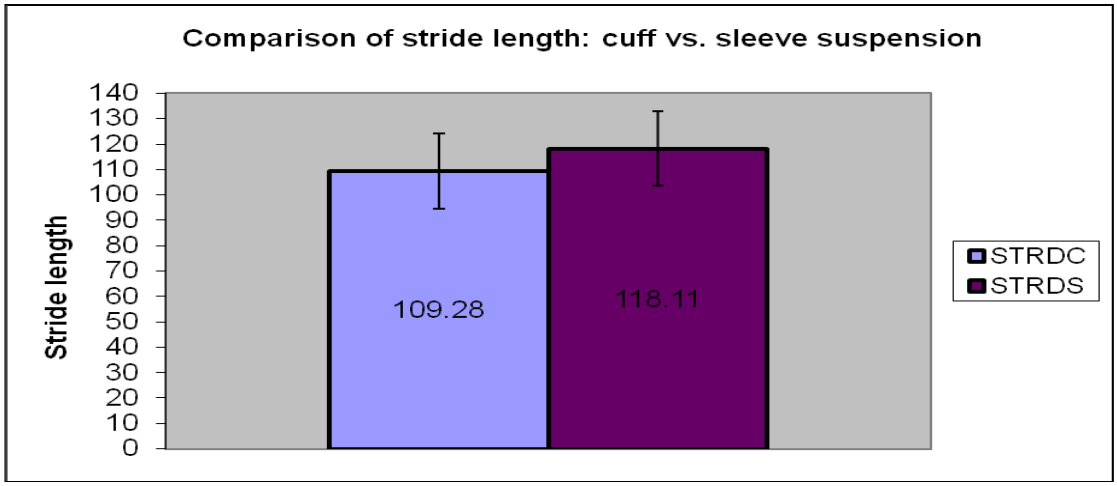


Fig. A

Table-C: Comparison of Step length: Cuff suspension vs. Sleeve suspension (N=30)
Paired samples t-test between STPC-STPS

STEP LENGTH	Mean ±SD	t-value	p-value
STPC	54.76±7.48	-5.908**	.000
STPS	59.06±7.32		
**-Significant at 0.05 level			

STPC – STEP LENGTH WITH CUFF SUSPENSION
STPS – STEP LENGTH WITH SLEEVE SUSPENSION

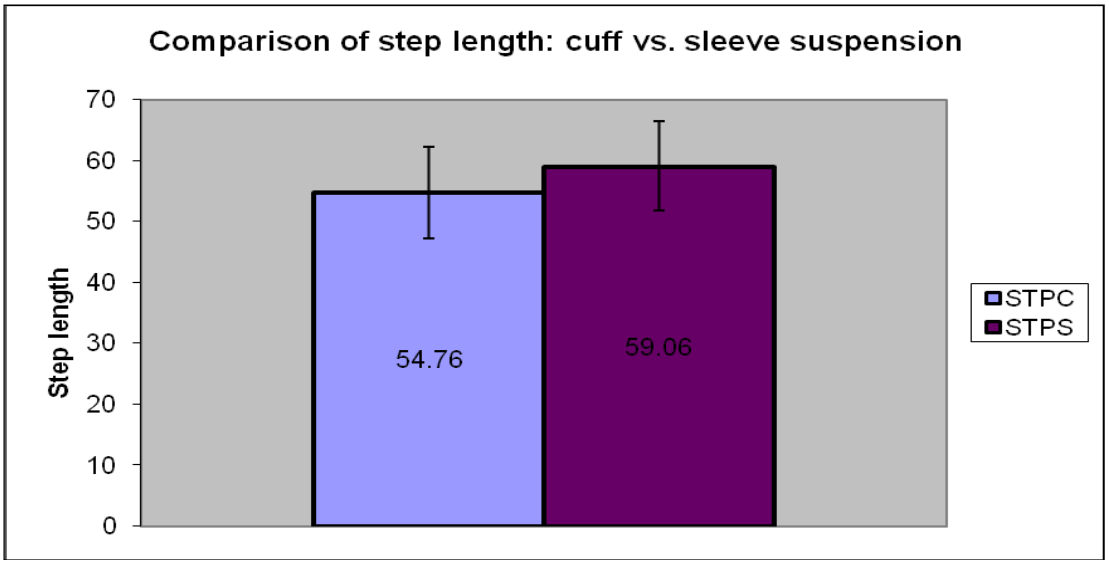


Fig. B

Table-D: Comparison of velocity: Cuff suspension vs. Sleeve suspension (N=30)
Paired samples t-test between SPEEDC-SPEEDS

VELOCITY	Mean ±SD	t-value	p-value
SPEEDC	.76±.12	-11.667**	.000
SPEEDS	.84±.14		
**-Significant at 0.05 level			

SPEEDC – VELOCITY WITH CUFF SUSPENSION
SPEEDS – VELOCITY WITH SLEEVE SUSPENSION

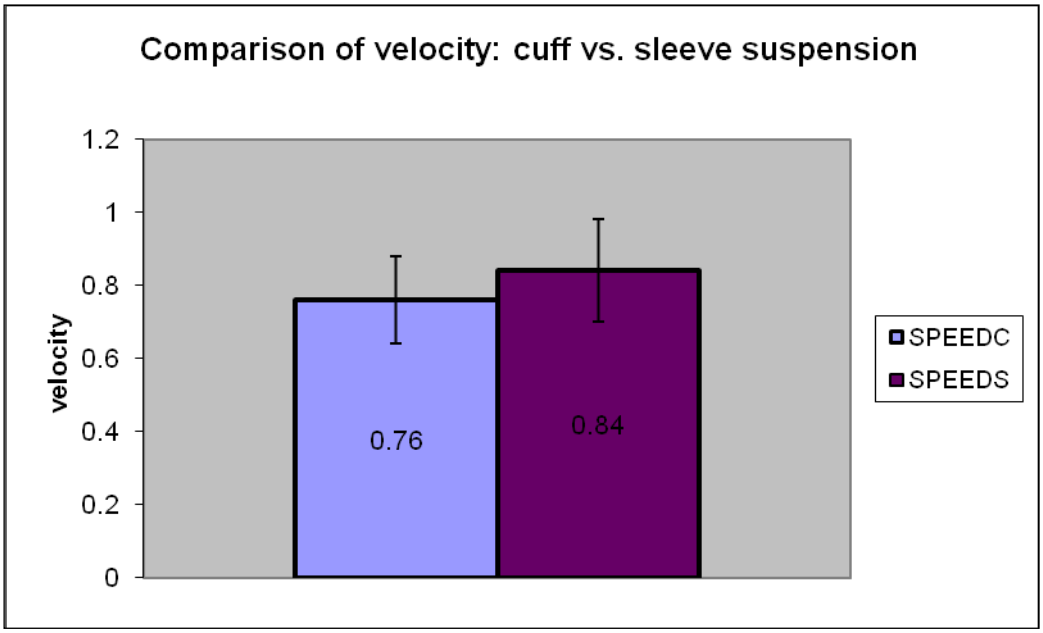


Fig. C

Table-E: Comparison of cadence: Cuff suspension vs. Sleeve suspension (N=30)
Paired samples t-test between CDNC-CDNS

CADENCE	Mean ±SD	t-value	p-value
CDNC	75.27±10.35	-2.039^{NS}	.051
CDNS	78.17±11.20		
NS- Non Significant at 0.05 level			

CDNC - CADENCE WITH CUFF SUSPENSION
CDNS - CADENCE WITH SLEEVE SUSPENSION

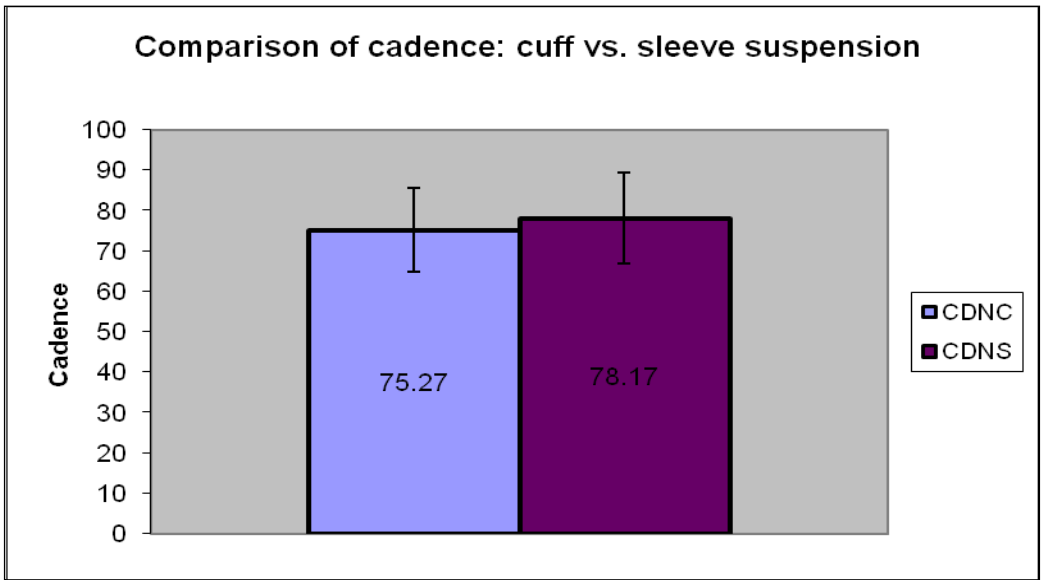


Fig. D

Table-F: Comparison of PCI: Cuff suspension vs. Sleeve suspension (N=30)
Paired samples t-test between PCIC-PCIS

PCI	Mean ±SD	t-value	p-value
PCIC	.73±.19	6.536**	.000
PCIS	.60±.14		
**-Significant at 0.05 level			

PCIC – PHYSIOLOGICAL COST INDEX WITH CUFF SUSPENSION
PCIS – PHYSIOLOGICAL COST INDEX WITH SLEEVE SUSPENSION

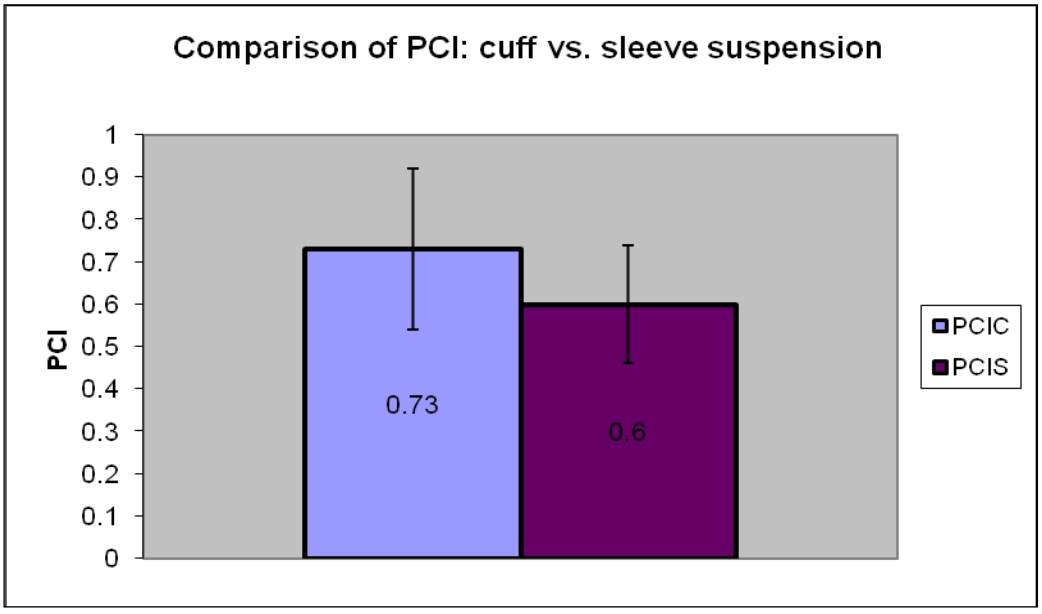


Fig. E



Fig F: Subject is walking on the Walkway

DISCUSSION

It has already been studied that energy expenditure in transtibial amputee is more than able bodied person. The fact is also established that interchanging of prosthetic components has influence over energy expenditure and gait characteristics by various studies. As suspension system is a vital component of the prosthesis, the present study aims to find out the effect of two commonly prescribed suspension systems i.e. cuff suspension and sleeve suspension on energy expenditure and stride characteristics in unilateral patella tendon bearing prosthesis users. The result suggested that the subjects were benefitted by the sleeve suspension significantly over cuff suspension. The comparison of post test scores of cuff suspension & sleeve suspension for step length (P-value .000, t-value -5.908) shows significant difference. The comparison of post test scores of cuff suspension & sleeve suspension for stride length (P-value .000, t-value -5.842) shows significant difference. The comparison of post test scores of cuff suspension & sleeve suspension for velocity (P-value .000, t-value -11.667) shows significant difference. The comparison of post test scores of cuff suspension & sleeve suspension for cadence (P-value .051, t-value -2.039) shows no significant difference. The comparison of post test scores of cuff suspension & sleeve suspension for energy expenditure (P-value .000, t-value -5.908) shows significant difference. The improvement in stride length, step length and velocity is supported by the previous study [4] by Roy W. Wirta who found least deviation with sleeve suspension with below knee amputees than other suspension systems.

The cadence shows no significant changes. This result correlates with the earlier studies by the Power et al (1996) in which he found that the cadence was not significantly changed in a comparison of five prosthetic feet [9]. The significant improvement in energy expenditure also supports the fact

that with proper suspension the metabolic cost also reduced. This result is also supported by various studies [10] those after changing the prosthetic components found energy efficient gait.

CLINICAL IMPLICATION

The findings of this study suggest that the use of sleeve suspension in unilateral transtibial patella tendon bearing prosthesis users is significantly more beneficial than cuff suspension over stride characteristics and energy expenditure. So the reduction in energy expenditure and improvement in stride characteristics by the sleeve suspension makes it the more appropriate prescription than cuff suspension for unilateral transtibial patella tendon bearing prosthesis users.

FUTURE RESEARCH

This study was conducted over traumatic unilateral transtibial amputee subjects. The future research over vascular subject group can possibly provide more information about this particular suspension effectiveness.

Conclusion: This study concludes that although both the suspension systems are prescribed for unilateral transtibial patella tendon bearing prosthesis users, the sleeve suspension is more beneficial than the cuff suspension in terms of stride parameter and energy expenditure.

Declaration by Authors

Acknowledgement: None
Source of Funding: None
Conflict of Interest: No conflicts of interest declared.

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How to cite this article: Sanket Kumar Rout, Priyanka Behera, Sonali Mishra, Anjani Kumar Sinha. Sleeve vs. cuff suspension: effect on stride parameter and energy expenditure in unilateral transtibial patella tendon bearing prosthesis users. *International Journal of Research and Review*. 2026; 13(11): 154-161. DOI: *https://doi.org/10.52403/ijrr.20261113*

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