论著·军事医学

血流限制下跑步热身对篮球运动员跟腱形态及功能急性的影响

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[摘要] **目的** 分析血流限制(blood flow restriction, BFR)下跑步热身对篮球运动员跟腱形态及功能的急性影响,为易发跟腱损伤的军人和运动员探索更适合的跑步热身方案提供理论依据。**方法** 27名男性篮球运动员参与3次不同方案的跑步热身,分别为低速度跑步(low-speed running,LSR)、高速度跑步(high-speed running,HSR)和BFR-LSR。分析比较3次测试中受试者的跟腱形态、性能及功能表现的急性变化。**结果** 运动后即刻,与LSR热身相比,HSR热身与BFR-LSR热身可显著改善跟腱厚度、血流、刚度和腓肠肌最大自主等长收缩(maximal voluntary isometric contraction,MVIC),差异具有统计学意义($P<0.05$),且BFR-LSR热身与HSR热身之间无统计学差异($P>0.05$);运动后24 h,与LSR热身相比,HSR热身仍可显著改善跟腱厚度、血流、刚度和腓肠肌MVIC($P<0.05$),而BFR-LSR热身后的各项指标虽然与LSR热身相比未呈现统计学显著差异,但仍呈现出正向趋势。运动后即刻和运动后24 h,三种热身方式在跳跃功能表现方面均未存在显著性差异($P>0.05$),但BFR-LSR热身和HSR热身相较于LSR热身表现出更优结果。**结论** 运动后即刻,BFR-LSR热身在提高跟腱形态和性能、改善跳跃表现方面可以达到与HSR热身相似的效果,但其持续和长期影响仍需进一步验证。

[关键词] 血流限制训练;跑步热身;跟腱形态及功能;表面肌电

[中图法分类号] G804.2;R322.73;R331.3 [文献标志码] A

Acute effects of blood flow restriction running warm-up on Achilles tendon morphology and function in basketball athletes

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[**Abstract**] **Objective** To determine the acute effects of blood flow restriction (BFR) running warm-up on Achilles tendon morphology and function in basketball players in order to provide a theoretical basis for optimizing warm-up protocols for military personnel and athletes susceptible to Achilles tendon injuries. **Methods** Twenty-seven male basketball players were subjected and asked to participate in 3 different running warm-up protocols: low-speed running (LSR), high-speed running (HSR), and BFR combined with

[基金项目] 陕西省自然科学基础研究计划项目(2021JM-530)

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引用格式:李婧,潘玮敏,樊竞远,等. 血流限制下跑步热身对篮球运动员跟腱形态及功能急性的影响[J]. 陆军军医大学学报,2025,47(18):2154-2162. DOI:10.16016/j.2097-0927.202505013.

Citation:LI JING, PAN WEIMIN, FAN JINGYUAN, *et al*. Acute effects of blood flow restriction running warm-up on Achilles tendon morphology and function in basketball athletes[J]. J Army Med Univ,2025,47(18):2154-2162. DOI:10.16016/j.2097-0927.202505013.

LSR (BFR-LSR). The acute changes in Achilles tendon morphology, mechanical properties, and functional performance across the 3 testing sessions were analyzed and compared. **Results** Immediately after training, both HSR warm-up and BFR-LSR warm-up significantly improved Achilles tendon thickness, blood flow, stiffness, and gastrocnemius maximal voluntary isometric contraction (MVIC) when compared with LSR warm-up ($P<0.05$). No statistical differences were observed in above indicators between the BFR-LSR and HSR warm-ups ($P>0.05$). 24 hours after training, compared with LSR warm-up, HSR warm-up still significantly improved Achilles tendon thickness, blood flow, stiffness, and gastrocnemius MVIC ($P<0.05$). Although BFR-LSR warm-up did not show statistically significant differences in these parameters compared to LSR warm-up, it still demonstrated positive trends. Immediately and 24 h after training, no obvious difference were found in jump performance among the 3 warm-up protocols ($P>0.05$), but, both BFR-LSR and HSR warm-ups exhibited superior performance than LSR warm-up. **Conclusion** Immediately after training, BFR-LSR warm-up demonstrates comparable effects to the HSR warm-up on improving Achilles tendon morphology and performance, as well as enhancing jump performance. However, its sustained and long-term effects require further investigation.

[**Key words**] blood flow restriction training; warm-up running; Achilles tendon morphology and function; surface electromyography

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跟腱(achilles tendon, AT)作为人类完成走、跑、跳等动作的关键结构,在运动中承受着较大的机械应力,相比其他肌腱更易损伤[1]。长期重复性过度力学载荷是跟腱损伤的常见诱发因素,好发于军人和运动员等群体。流行病学研究显示,跟腱损伤是军人常见的一种高发运动性疾病[2-3],对篮球运动员的职业生涯也会造成极大影响,约40%的运动员在损伤后无法重返赛场[4]。急性或慢性跟腱损伤后,极易引发疼痛、肿胀等症状,导致运动期间肢体的负荷耐受性和功能下降[5]。

运动前的热身训练对于预防跟腱损伤的效果已被证实[6-7],而跑步热身是现阶段最有效也是最广泛的热身方式之一[8],目前推荐的跑步热身速度为8~10 km/h[9-11]。在此范围内,PIETERS等[7]对比研究发现,健康青年人以9.72 km/h的高速度跑步热身可引起跟腱血流量和刚度即刻增加,对于降低随后运动过程中的损伤风险并提高后续运动表现具有明显益处,然而对于军人及篮球运动员等长期从事运动训练的专业人员而言,高速度跑步热身对跟腱所产生的累积应力,仍可能是引发跟腱过度使用性运动损伤的重要危险因素[12],而且该研究仅关注了运动后的即刻效应,未对其24 h内的短期急性后续影响进行评估。鉴于现阶段尚无研究结果表明低速度跑步热身可产生显著提高跟腱性能的急性效果,因此寻求适用于此人群的低速度跑步热身策略,以期达到与高速度跑步热身对跟腱产生类似的良性促进作用十分必要。

近年来血流限制(blood flow restriction,BFR)训练被广泛用于康复医学及运动训练领域[13-14],它是通过在肢体近端放置充气袖带,使静脉血流闭塞的同时部分阻塞动脉血流以提高训练效果[15-16]。业已证实,BFR结合低强度抗阻训练能够产生与高强度抗阻训练相似的肌腱形态、性能等适应效果[17-18]。但是,抗阻训练是相对静态的固定负重训练,而在跑步热身中跟腱需要适应动态、多方向的阻力变化,从而增强肌肉力量传递效率,尤其对于高强度任务要求的军人和运动员更为必要。基于此,本研究探索性地将BFR结合低速度跑步热身应用于篮球运动员,并将其与高速度跑步热身进行对比分析,观察二者运动后即刻及运动后24 h对跟腱形态和功能的急性效果,以期为军队各类高强度训练方案的优化设计提供新的思路和视角,从而提升训练效能和人员健康水平,同时为后续预防跟腱损伤长期影响的深入研究奠定坚实的理论基础。

1 资料与方法

1.1 研究对象

本实验于2024年12月进行,选择西安市高校27名男性篮球运动员为研究对象,运动等级为二级及以上,年龄(22.0±2.39)岁,身高(183.3±3.06)cm,体质量(77.17±8.27)kg。所有受试者为自愿参加,无跟腱疼

痛、跟腱损伤或下肢严重创伤病史,不吸烟,无心血管及中枢神经系统疾病,此外还建议受试者在研究期间不要服用可能影响结果的药物如喹诺酮类或皮质激素等[19]。充分告知本研究的具体内容和注意事项,均签署知情同意书,要求受试者在此期间遵循正常饮食,确保充足睡眠,测试前48 h内和测试后24 h内禁止高强度体育活动。本研究已通过西安体育学院伦理委员会审核批准(XAIPE2024036),中国临床试验注册中心注册(注册号ChiCTR2400094309)。

1.2 研究工具

LOGIQ Book XP彩色多普勒超声(美国,GE Healthcare公司)、无线microFET3(美国,HOGGAN公司)、三维测力台(瑞士,KISTLER公司,9287C,90 cm×60 cm×10 cm,采样频率500 Hz,采样时间5 s)、无线遥感表面肌电测试仪(美国,NORAXON公司)、血流加压训练带(中国河南,T-BFR-0355,长约17 cm,宽约10 cm)、HPCOSMOS专业运动跑台(德国,H/P/COSMOS公司)。

1.3 研究方法

采用G*Power 3.1软件计算样本量,效应量为0.25,显著性水平α=0.05,检验效能1−β=0.8[20],计算得到总样本量为15例,实际招募27例。采用重复测量交叉设计,27名受试者在正式训练前完成基线测量和统计,包括年龄、身高、优势侧[21]、动脉闭塞压(arterial occlusion pressure,AOP)等。

完成基线指标测量后1周,每位受试者均接受3次时长为10 min的不同方式跑步机跑步热身训练,为确保身体机能充分恢复及规避交互影响[20, 22],受试者每隔1周进行1次热身训练,并在每次训练后接受相应的指标测试。3次不同方式跑步热身训练分别为低速度跑步(low-speed running,LSR)、BFR-LSR和高速度跑步(high-speed running,HSR)。其中LSR训练仅为跑步热身,热身速度为8 km/h;BFR-LSR训练在跑步热身同时于优势侧膝关节腘横纹上缘平行处放置BFR袖带[23],运动期间以50%AOP进行加压[17],运动过程中袖带全程充气,结束后解除BFR压力;HSR训练仅为跑步热身,热身速度为9.72 km/h(图1)。

1.4 测量方法

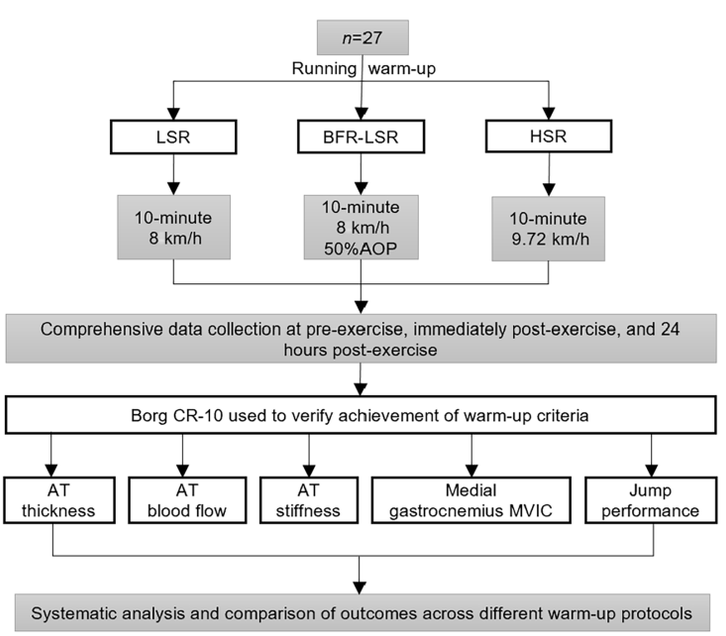
AOP测量方法[23]:受试者先仰卧位休息10 min,之后在优势侧膝关节腘横纹处放置BFR充气袖带,同时将多普勒超声探头放置在胫后动脉上观察脉搏搏动,之后逐步增加袖带压力,直至搏动消失,此时的压力即为AOP。

1.5 测量指标

干预前、干预后即刻和干预后24 h[24]测量以下指标进行评价。

1.5.1 主观疲劳度测量

采用Borg CR-10量表(Borg Category-Ratio-10 Scale)评估运动中的主观努力强度或疲劳感。评分范围是0~10分,代表从完全没有感到努力到极度困难的程度。0分表示没有努力,10分



LSR: Low-speed running; BFR: Blood flow restriction; HSR: High-speed running; AT: Achilles tendon; MVIC: Maximal voluntary isometric contraction

图1 实验路线图

Figure 1 Flowchart of experimental procedure

表示极度困难无法继续。每次训练结束时,对受试者进行Borg CR-10评估并记录。

1.5.2 跟腱形态测量 应用便携式彩色多普勒超声仪采集受试者的跟腱厚度和血流。测量时受试者俯卧于治疗床,踝关节悬挂在治疗床末端,保持中立位,于距腱止点2 cm位置测量跟腱厚度[25],并测量腓动脉血流量[26],测量3次,取平均值。

1.5.3 跟腱刚度测量 无线microFET3测量受试者的跖屈肌力,换算得出跟腱力,同时使用彩色多普勒超声测量腓肠肌内侧肌肉收缩和舒张时的长度变化量,通过跟腱力除以长度变化量得出跟腱刚度[27-29]。

1.5.4 腓肠肌最大等长肌力 采用无线遥感表面肌电测试仪测量受试者优势侧腓肠肌最大等长肌力。局部皮肤毛发清理,酒精消毒,将电极片顺着肌纤维走向贴于腓肠肌内侧的肌腹膨隆处,所有电极均由同一研究人员放置。测量受试者在进行肌肉收缩和舒张时的长度变化量,同时进行肌电数据记录,重复3次最大自主等长收缩(maximal voluntary isometric contraction,MVIC),持续6 s。选择中间2 s肌电信号计算MVIC,取平均值。

1.5.5 跟腱功能测量 应用Kistler三维测力台进行下落跳跃(drop jump,DJ)和反向运动跳跃(counter movement jump,CMJ)进行评价。受试者于40 cm跳台进行下落跳跃[30],通过地面反作用力曲线确定地面接触时间(ground contact time,GCT);并在测力台上进行反向运动跳跃,确定跳跃高度,测量3次,取平均值。

1.6 统计学分析

应用SPSS 26.0(IBM USA)软件进行数据统计分析。使用Shapiro-Wilk对所有测试指标进行正态分布检验,若数据服从正态分布,则用$\bar{x}\pm s$表示;若不服从正态分布,则用$M(P_{25},P_{75})$表示。符合正态分布的数据采用重复测量方差分析,通过Mauchly Test判断是否符合球形假设,若不符合,使用Greenhouse-Geisser correction进行校正,Bonferroni法用于事后两两比较,总体检验水准设置为0.05,参数可信区间取95%。非正态分布数据组间比较采用Kruskal-Wallis检验,组间两两比较采用Bonferroni法,$P<0.05$表示差异有统计学意义。

2 结果

2.1 主观疲劳度

不同热身方式后CR-10结果显示,BFR-LSR热身和LSR热身的中位数均为3,HSR热身的中位数为4。BFR-LSR热身、HSR热身均与LSR热身之间存在显著性差异($P<0.05$,表1)。

表1 不同热身方式后CR-10对比分析[n=27,$M(P_{25},P_{75})$]

Table 1 Comparison of CR-10 score in the athletes after different warm-up protocols[n=27,$M(P_{25},P_{75})$]

Warm-up Protocols	CR-10 Score	P		
		BFR-LSR *vs* LSR	HSR *vs* LSR	BFR-LSR *vs* HSR
LSR	3.0(3.0, 3.0)			
BFR-LSR	3.0(3.0, 4.0)	0.014	<0.001	0.455
HSR	4.0(3.0, 4.0)			

CR-10: Borg category-ratio-10 scale; LSR: Low-speed running; BFR: Blood flow restriction; HSR: High-speed running

2.2 不同热身方式后跟腱厚度的变化情况

运动后即刻,BFR-LSR热身和HSR热身后的跟腱厚度均显著低于LSR热身($P<0.05$)。运动后24 h,HSR热身后的跟腱厚度仍显著低于LSR热身($P<0.05$),BFR-LSR热身与LSR热身之间无显著性差异,但BFR-LSR热身的厚度仍低于LSR热身(表2)。

2.3 不同热身方式后跟腱血流的变化情况

运动后即刻,BFR-LSR热身和HSR热身的血流量均显著高于LSR热身($P<0.05$)。运动后24 h,HSR热身后的血流量仍显著高于LSR热身($P<0.05$),BFR-LSR热身与LSR热身之间无显著性差异,但BFR-LSR热身的血流量高于LSR热身(表2)。

2.4 不同热身方式后跟腱刚度的变化情况

运动后即刻,BFR-LSR热身和HSR热身后的跟腱刚度均显著高于LSR热身($P<0.05$)。运动后24 h,HSR热身后的跟腱刚度仍显著高于LSR热身($P<0.05$),BFR-LSR热身与LSR热身之间无显著性差异,但BFR-LSR热身的刚度仍高于LSR热身(表2)。

2.5 不同热身方式后腓肠肌内侧MVIC的变化情况

运动后即刻,BFR-LSR热身和HSR热身后的腓肠肌内侧MVIC均显著高于LSR热身($P<0.05$)。运动后24 h,HSR热身后的腓肠肌内侧MVIC仍显著高于LSR热身($P<0.05$),BFR-LSR热身与LSR热身之间无显著性差异,但BFR-LSR热身的腓肠肌内侧MVIC仍高于LSR热身(表2)。

2.6 不同热身方式后跳跃表现的变化情况

运动后即刻,3组GCT均有下降趋势,运动后24 h恢复,但无显著性差异,热身方式*时刻交互作用不显著($P>0.05$,$\eta^2=0.016$)。运动后即刻,3组CMJ高度均有增高趋势,运动后24 h恢复,但无显著性差异,热身方式*时刻交互作用不显著($P>0.05$,$\eta^2=0.088$,表3)。

表2 不同热身方式在跟腱厚度、血流、刚度、腓肠肌内侧MVIC对比分析（n=27，$\bar{x}\pm s$）

Table 2 Comparison of Achilles tendon thickness, blood flow, stiffness, and medial gastrocnemius MVIC across different warm-up protocols（n=27，$\bar{x}\pm s$）

Outcomes	Time Point	LSR	BFR-LSR	HSR	*P*		
					BFR-LSR *vs* LSR	HSR *vs* LSR	BFR-LSR *vs* HSR
AT thickness/mm	Baseline	0.416±0.025	0.416±0.025	0.416±0.025	–	–	–
	Immediately post-exercise	0.408±0.031	0.393±0.023	0.385±0.023	0.017	0.004	0.147
	24 h post-exercise	0.412±0.023	0.402±0.026	0.397±0.027	0.089	0.029	0.521
AT blood flow/(mL/min)	Baseline	34.87±8.01	34.87±8.01	34.87±8.01	–	–	–
	Immediately post-exercise	40.24±8.73	51.76±16.55	57.39±18.78	0.001	<0.001	0.077
	24 h post-exercise	34.89±7.48	39.85±13.46	42.12±10.56	0.125	0.004	1.000
AT stiffness/(N/mm)	Baseline	239.33±63.16	239.33±63.16	239.33±63.16	–	–	–
	Immediately post-exercise	240.24±56.76	267.56±32.20	273.97±41.04	0.028	0.024	1.000
	24 h post-exercise	239.66±64.31	255.26±36.72	270.07±59.81	0.536	0.032	0.630
Medial gastrocnemius /(MVIC/μV)	Baseline	400.56±120.04	400.56±120.04	400.56±120.04	–	–	–
	Immediately post-exercise	414.68±97.68	471.07±98.34	483.72±104.16	0.012	0.001	1.000
	24 h post-exercise	399.60±124.03	427.35±105.98	453.28±91.29	0.433	0.018	0.573

LSR: low-speed running; BFR: blood flow restriction; HSR: high-speed running; AT: Achilles tendon; MVIC: maximal voluntary isometric contraction

表3 不同热身方式在跳跃表现对比分析（n=27，$\bar{x}\pm s$）

Table 3 Comparison of jump performance across different warm-up protocols（n=27，$\bar{x}\pm s$）

Outcomes	Time Point	LSR	BFR-LSR	HSR	*P*	η^2
GCT/s	Baseline	0.243±0.026	0.243±0.026	0.243±0.026		
	Immediately post-exercise	0.242±0.028	0.236±0.024	0.234±0.024	>0.05	0.016
	24h post-exercise	0.250±0.019	0.245±0.024	0.243±0.023		
CMJ height /cm	Baseline	34.48±6.44	34.48±6.44	34.48±6.44		
	Immediately post-exercise	35.42±6.55	36.13±7.06	37.00±6.96	>0.05	0.088
	24h post-exercise	33.24±6.72	34.36±7.07	35.76±6.30		

LSR: Low-speed running; BFR: Blood flow restriction; HSR: High-speed running; GCT: Ground contact time; CMJ: Counter movement jump. *P*: Warm-up protocols*time point; η^2: Warm-up protocols*time point

3 讨论

科学合理的热身对于跟腱的生理功能和运动表现具有保护和促进作用，如增强跟腱局部血液循环，促进氧气和营养物质供应；优化跟腱的力学特性，增强跟腱的抗损伤能力等，这些参数在优化跟腱应力分布、降低损伤易感性和提升运动效能方面具有重要意义[7, 31]。美国国家体能协会（the National Strength and Conditioning Association，NSCA）规定 Borg CR-10 评分3~5分达到热身要求[32]，本研究中3种热身方式均达到热身要求，尽管HSR热身和BFR-LSR热身与LSR热身均存在统计学差异，但BFR-LSR热身的分值与LSR热身的分值相近，表明其强度较低，具有更高的个体可接受性。

对于从事高强度任务的军人及运动员群体而言，长期执行此类任务会导致跟腱厚度增加[33]、跟腱血管对运动负荷反应的减弱，从而增加跟腱损伤风险[34]。本研究结果显示，在满足热身要求的基础上，运动后即刻，与LSR热身相比，BFR-LSR热身可显著降低跟腱厚度、提高跟腱血流量，效果与HSR热身相似。研究证实HSR热身时产生的较大机械应力，能够使肌腱基质内流体静压增加，使液体从跟腱本身移动到腱周区域；同时运动时腱周压力显著下降[35]，可进一步促使腱内液体向腱周移动。被挤出的液体沿着跟腱外表面积聚，形成相对较大的液体区域[36]，跟腱组织水合状态发生改变，跟腱厚度降低[23]。在此同时HSR热

身时机体能量消耗增加,腱周组织的氧饱和度下降,局部氧输送和代谢需求增加[37],跟腱由于需要更多的氧气、营养物质供应以及代谢废物清除的需求,诱导跟腱生理性血流增加[38]。此外,LANGBERG和RÖSEN等[39-40]研究发现,运动时肌腱组织内的缓激肽浓度上升,使得运动时腱周血管扩张,也是运动引起腱周血流量增加的重要因素。

本研究中BFR-LSR热身运动后即刻可以获得与HSR热身相似的跟腱厚度降低和血流量增加效果。关于此效果的具体机制虽然在本研究中未做验证,但是基于以往研究结果[23, 41],推测其一是由于BFR-LSR热身时使用的充气压力袖带间接产生了与HSR热身相似的机械应力,使得原本在静止或无负荷状态下呈波浪状排列的跟腱胶原纤维被拉直,液体从跟腱核心移动到腱周[42],跟腱厚度减小;其二不同于HSR热身中跟腱血流增加的主动性需求,BFR-LSR热身中充气压力袖带所营造的缺血缺氧环境能够促进血管生成和血管扩张,增强跟腱区域的血液供给。研究发现其中低氧诱导因子(hypoxia-inducible factor 1,HIF-1)可上调血管内皮生长因子(vascular endothelial growth factor,VEGF)的表达[43],提高腱周区域的血管密度,而且VEGF可促进一氧化氮等血管扩张因子的释放[44],血管管径扩张,使得血流增加[45];当充气压力袖带去除后,下肢血流再灌注,血流量急剧增加,帮助清除由于BFR缺血缺氧而导致的代谢物累积并带来新的营养物质[46]。本研究发现运动后24 h,跟腱形态学的结果显示,HSR热身与LSR热身两者之间仍存在显著差异,BFR-LSR热身与LSR热身相比虽未显示出显著差异,但呈现出正向趋势,提示BFR-LSR热身的急性效应明显,但其长期影响仍需进一步研究验证。

在分析了不同热身方式对跟腱形态的影响后,本研究进一步探讨了其对跟腱性能的影响。对于跟腱而言,较高的刚度有助于力量的高效传输,在运动中能够承载更大的负荷,从而提升跟腱整体的力学性能表现。腓肠肌内侧MVIC作为与跟腱刚度紧密相关的肌力指标,能够反映肌腱-肌肉单位在力学作用下的协同响应。本研究显示,运动后即刻,与LSR热身相比,BFR-LSR热身可以显著提高跟腱刚度和腓肠肌内侧MVIC,效果与HSR热身相似。HSR热身后跟腱水合状态发生改变,进而影响跟腱的材料性能,导致跟腱脱水从而使得跟腱刚度增加[7];同时运动中血流和氧气供应的增加有助于提高腓肠肌的局部代谢能力,从而增强其能量供应效率,支持肌肉在运动中的持续力量输出[47]。而在BFR-LSR热身中,一方面充气压力袖带产生的与HSR热身相似机械应力可能间接影响跟腱的水合状态,从而导致跟腱刚度发生变化;另一方面,BFR的使用可能会增加碱性成纤维细胞生长因子(basic fibroblast growth factor,bFGF)的分泌[48]。bFGF可以增强成纤维细胞增殖[49],使得胶原合成速率增加[50],跟腱刚度增加、抗张力能力增加;除此之外,BFR训练可能通过增加肌内代谢应激水平[51-52],如乳酸等代谢产物的积累,激活更高阈值的Ⅱ型运动单位,从而促使腓肠肌进行更强的收缩反应[53]。与跟腱形态学指标结果相似,本研究发现运动后24 h,相较于LSR热身,HSR热身后跟腱刚度显著更高,腓肠肌内侧MVIC显著更高,而BFR-LSR热身与LSR热身之间已无显著性差异,因此BFR-LSR热身对于跟腱性能的短期干预效果显著,与HSR热身效果相似,然而如何持续24 h后的稳定性仍是后续研究优化的关键。

热身旨在支持后续运动表现,增强机体功能和运动效率,本研究进而评估了热身对后续运动表现的影响。下落跳跃中较短的GCT通过跟腱传递力而实现,CMJ高度与跟腱刚度之间存在正相关性[54]。本研究结果显示,运动后即刻和运动后24 h,与LSR热身相比,尽管BFR-LSR热身和HSR热身无论是GCT还是CMJ高度均未显示显著性差异,但均呈现出良性趋势,推测可能与本次测试仅为单次短时测量,未涉及长期观测有关,这一结果为长期应用提升运动表现奠定了潜在理论基础。

综上所述,BFR-LSR热身能够达到HSR热身对跟腱相似的形态和功能改善效益,且强度较低,具备更高的个体可接受性。鉴于热身后需进行高强度活动,在运动前实施相对强度较低的热身能够在有效激活生理机能的同时避免过早的能量消耗,从而实现热身效果与体能储备的优化平衡,可以作为满足高强度任务需求的军人和运动员的热身选择。但是本研究仅测量和记录了干预前后和24 h的即时数据,后续需开展长期对照观察,在一段持续且稳定的时间周期内,对相关变量进行系统监测与数据采集。此外,由于BFR-LSR热身在24 h后的持续效果较弱,因此未来的研究应从BFR应用的方式,包括充气袖带压力设置及放置解剖位置,以及热身的持续时间等方面进一步深入筛选评估,以确定最优应用设置。同时,是否通过每周增加BFR-LSR热身的训练频率来弥补其不足也将是未来深化研究的重要方向,以期为BFR-LSR热身在军人及运动员群体损伤预防、运动表现提升及身体机能改善方面提供更加科学合理的干预策略。

利益冲突 本文所有作者声明不存在利益冲突

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(收稿:2025-05-07;修回:2025-07-23)

(编辑 邓强庭)