Thursday, May 20			
Start Time (UTC)	**Finish Time (UTC)**	**Event**	**Presenter**
2:00pm	**3:00pm**	**Welcome & HMV/GPB Joint Podium Session**	
2:05pm		BAYES'D AND CONFUSED: BAYESIAN INFERENCE CLARIFIES THE NEURAL CONTROL OF BALANCE AMID SENSORY UNCERTAINTY	Ty Whittier
2:15pm		COMPLEXITY OF NEURAL CONTROL DURING ISOMETRIC FORCE PRODUCTION	Peter Raffalt
2:25pm		IMPACTS OF IMPAIRED MICROCIRCULATORY FUNCTION ON SKELETAL MUSCLE MITOCHONDRIAL FUNCTION IN PERIPHERAL ARTERY DISEASE	Liz Pekas
2:35pm		3D PRINTED ANATOMICAL MODELS IMPROVE STUDENT COMPREHENSION OF COMPLEX ANATOMY: A SYSTEMATIC REVIEW AND META-ANALYSIS	David Salazar
2:45pm		KINEMATIC DIFFERENCES BETWEEN PROFICIENT AND NON-PROFICIENT FREE THROW SHOOTERS	Dimitrije Cabarkapa

BAYES'D AND CONFUSED: BAYESIAN INFERENCE CLARIFIES THE NEURAL CONTROL OF BALANCE AMID SENSORY UNCERTAINTY

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Presentation Preference: **Podium**

INTRODUCTION

While controlling a movement, the brain requires an accurate and timely estimate for the locations of all body parts involved in the task. This estimate is heavily dependent on incoming sensory information. However, all sensory information is inherently variable and clouded with uncertainty [1]. Bayesian inference posits that the most accurate estimate for the location of a body part comes when considering the incoming sensory information as well as learned expectations [2]. The purpose of this study was to clarify if body position estimations involving full body stepping movements follow the Bayesian framework like prior work in simple hand movements. We hypothesized that as incoming sensory information becomes less certain, body position estimates will rely more on learned expectations.

METHODS

Using virtual reality (VR), we applied the methods of [3] to a full body stepping task. In VR, participants move a cursor (controlled by their center of mass) to a target box with varying amounts of visual feedback during their performance (Figure 1). In the first 100 trials, participants are trained to expect a shift (randomly drawn from the normal distribution N (μ = 7.5 cm, σ = 2.5 cm) to their cursor position throughout a trial. Once participants have learned to expect the shift, they complete 500 testing trials where the visual certainty of the cursor position varies. When participants believe the cursor is in the target box, they indicate by button press on the VR controller. The deviation from the target, along with the magnitude of cursor shift on every trial, are used to calculate the magnitude of reliance on memory gained from previous experiences (taken from the slope of the regression line).

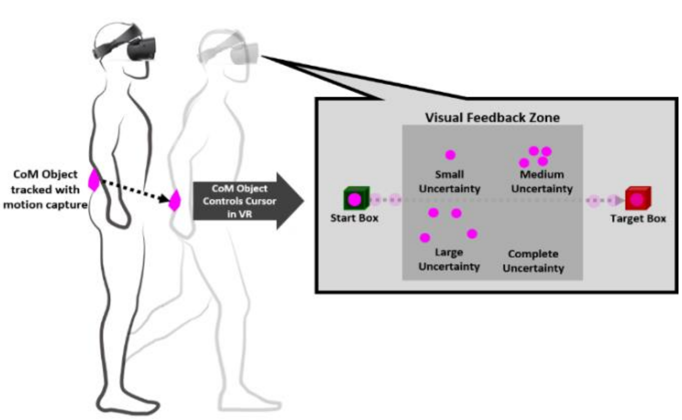

Figure 1. Participants move the cursor (controlled by their CoM and streamed by motion capture cameras) from the start box to the target box in VR. Visual feedback on cursor location is only given in the visual feedback zone and varies in certainty level.

RESULTS AND DISCUSSION

Twenty-one neurologically healthy females (aged 18-24) participated in this study. A RMANOVA indicated a significant effect of visual uncertainty level on the reliance of body position estimates on learned expectations ($p < .001$). Significant pairwise comparisons ($p < .001$) indicate that this reliance increases as sensory information becomes less certain (Figure 2). These results suggest that the nervous system compensates for sensory uncertainty by relying on expectations built from previous movement experiences. Furthermore, this behavior is not limited to simple hand movements, but rather, is consistent in multi-planar full body stepping movements.

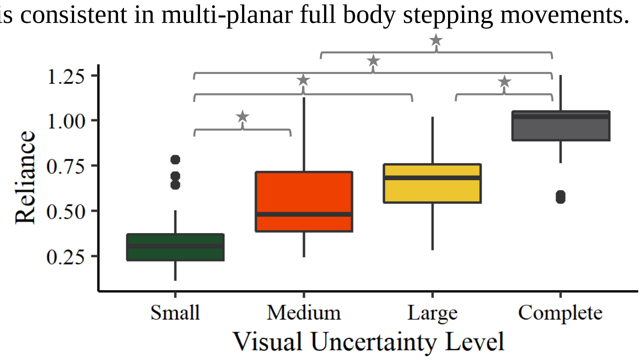

Figure 2. Reliance on learned expectations of body position across visual uncertainty conditions. Reliance = the slope of the regression line between the cursor shift and deviation from target on each trial. ★ = $p < .001$

CONCLUSIONS

Humans rely on sensory information to make proper motor control related decisions. However, differing light conditions, disease and injury can severely impair the quality of sensory information available. During ambulation, if sensory information fails to recognize a deviation from the expected outcome (a curb, object on the floor, etc.), harmful errors can occur if too much weight is placed on expectations. These results provide further evidence that the brain addresses the uncertainty of sensory cues when making body position decisions in a way consistent with a Bayesian Framework.

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COMPLEXITY OF NEURAL CONTROL DURING ISOMETRIC FORCE PRODUCTION

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Presentation preference: **Podium**

Introduction

Human movements contain a deterministic structure which has been shown to not originate from a linearly auto-correlated Gaussian process [1]. Pattern generators within the central nervous system containing oscillatory networks of neurons are believed to be responsible for this deterministic nature [2]. Based on this, two notions can be inferred: 1) neural activity measured through electroencephalography (EEG) and electromyography (EMG) and the corresponding muscular force contain a deterministic structure not originating from a linearly auto-correlated Gaussian process and 2) age-related changes in the complexity of movements (e.g. isometric force) originate from similar age-related changes in the temporal dynamics of the underlying neural activity. The purpose of the present study was to challenge these notions by measuring EEG, EMG and isometric force during submaximal planter- and dorsiflexion in children, adolescents, younger adults and older adults.

Methods

Twelve healthy children (male/female: 5/7; mean±SD age: 9.6±2.2 yrs; height: 1.46±0.18 m; mass: 34.5 ± 9.0 kg), thirteen adolescents (male/female: 9/4; mean±SD age: 15.5±1.8 yrs; height: 1.74±0.09 m; mass: 64.6 ± 10.1 kg), fourteen young adults (male/female: 6/8; mean±SD age: 22.1±1.7 yrs; height: 1.76±0.08 m; mass: 72.5 ± 16.4 kg), and fifteen older adults (male/female: 7/8; mean±SD age: 68.3±2.7 yrs; height: 1.73±0.11 m; mass: 81.5 ± 14.1 kg) completed 2 minutes of isometric plantar- and dorsiflexion at 10% of their maximal voluntary contraction force in a seated position with an ankle dorsiflexion angle of approximately 120°. Simultaneously, EEG was recorded from the sensorimotor cortex and EMG was recorded from the tibialis anterior (TA), soleus (SOL) and gastrocnemius (GAS) muscles. Surrogate analysis was used to evaluate if the structure of the signals was generated by a linearly auto-correlated Gaussian process and complexity of each signal was quantified using multiscale entropy. A one-way ANOVA with group as an independent variable was applied. In case of a significant effect of group, a Holm-Sidak post hoc test was applied to evaluate between-group differences.

Results and Discussion

The surrogate analysis revealed that for all participants and all trials, the structure of the EEG, EMG and force signals did not originate from a linearly auto-correlated Gaussian process excluding a non-deterministic underlying control process and supporting the first notion. There was no effect of group on the complexity of EEG during the two tasks or on the complexity of EMG from the GAS and SOL during the plantarflexion (Figure 1). The older adults had significantly lower complexity of the EMG from the TA during the dorsiflexion compared to the children ($p = 0.003$). For both tasks, the young adults had significantly higher complexity of the produced force compared to the two younger groups and the older group. These results do not support the second notion of age-related changes in the movement complexity originating from similar age-related changes in the neural activity complexity. This indicates that movement complexity does not solely originate from the nervous system but is modulated by other contributors as well (e.g. the mechanical properties of connective tissue).

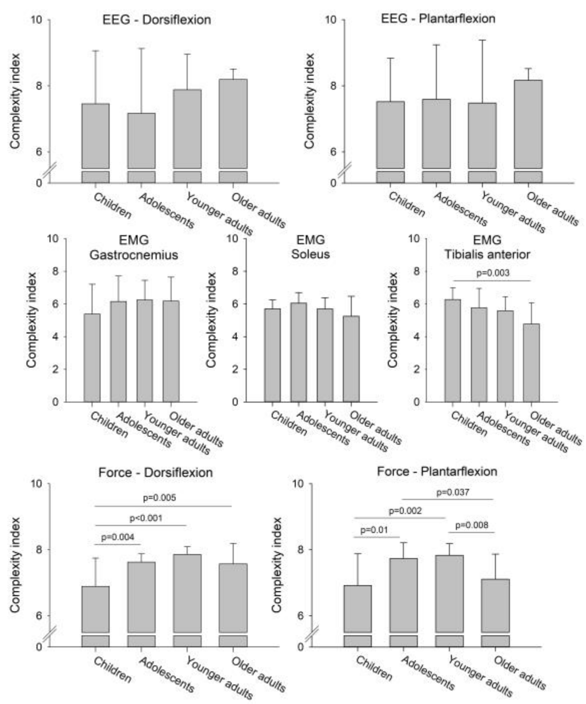

Figure 1: Complexity index for the EEG, the EMG from GAS, SOL and TA, and the force signal during plantar- and dorsiflexion for the four age groups.

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IMPACTS OF IMPAIRED MICROCIRCULATORY FUNCTION ON SKELETAL MUSCLE MITOCHONDRIAL FUNCTION IN PERIPHERAL ARTERY DISEASE

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Presentation Preference: **Podium**

INTRODUCTION

Peripheral artery disease (PAD) is a common atherosclerotic vascular disease which impairs blood circulation in the lower extremities. Patients with PAD often experience leg pain during walking early in the disease condition; however, this frequently progresses to a severe condition that includes foot ulcers which may require leg amputation [1]. Previous studies reported mitochondrial dysfunction and oxidative stress damage in the skeletal muscle of PAD patients, which may contribute to disease progression [2,3]. However, the exact mechanism underlying the skeletal muscle damage has not been examined. We sought to investigate skeletal muscle arteriole vasodilatory function as a key contributing mechanism for skeletal muscle mitochondrial dysfunction in PAD. We hypothesized that: 1) skeletal muscle arteriole endothelial-dependent vasodilatory function may attenuate skeletal muscle mitochondrial function in PAD, and 2) these decrements in vasodilatory function are associated with elevated leg vascular resistance assessed by ankle-brachial index (ABI, pressure difference between the upper and lower limb) and skeletal muscle mitochondrial respiratory function in patients with PAD.

METHODS

A total of 19 males with PAD (PAD, n=11) and male non-PAD control (CON, n=8) were recruited **(Table 1)**. Skeletal muscle tissue samples containing arterioles were harvested by primary operation or needle biopsy. Endothelium-dependent and independent vasodilation were assessed in response to: 1) flow-induced shear stress, 2) acetylcholine (ACh), and 3) sodium nitroprusside (SNP). Skeletal muscle mitochondrial respiratory function was assessed by high-resolution respirometry in using permeabilized skeletal muscle fibers methods.

RESULTS AND DISCUSSION

Endothelium-dependent vasodilation (flow and ACh) were significantly attenuated in patients with PAD ($p<0.05$) while endothelium-independent dilation showed no differences ($p>0.05$) **(Fig 1A)**. Complex I+II state 3 respiration was significantly lower ($p<0.05$) in PAD **(Fig 1B)**. Maximal endothelium-dependent vasodilation was strongly associated with complex I+II state 3 respiration for ACh ($r=0.6$) and flow ($r=0.7$) **(Fig 2)**. Additionally, ABI was moderately associated

Table 1. Participant characteristics (Mean ± SD, *$p<0.05$)

	CON (n=8)	PAD (n=11)
Age, y	64.6 ± 9.3	68.4 ± 10.2
Height, cm	180.2 ± 10.6	175.6 ± 3.7
Mass, kg	93.5 ± 20.6	74.1 ± 19.1*
Body mass index, kg/m^2	28.7 ± 5.0	23.5 ± 5.7
Ankle-brachial index	1.1 ± 0.1	0.6 ± 0.2*

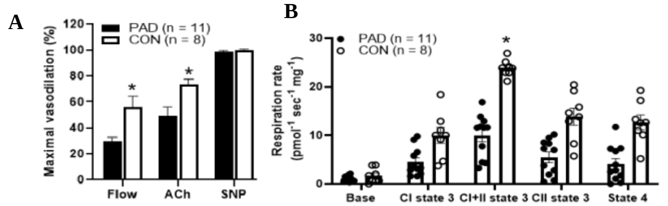

Figure 1: A) Maximal vasodilatory responses for flow, ACh, and SNP. **B)** Mitochondrial complex respiration. Mean±SEM, *$p<0.05$

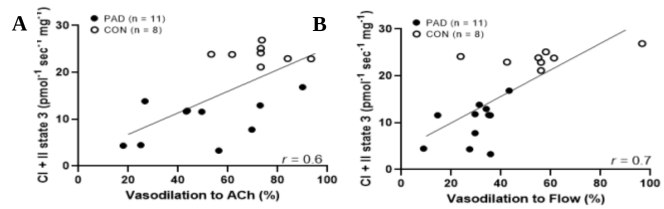

Figure 2: A) Association between maximal ACh vasodilation and complex I+II state 3 mitochondrial respiration. **B)** Association between flow and complex I+II state 3 mitochondrial respiration.

with maximal vasodilation to ACh ($r=0.4$) and flow ($r=0.5$), and mitochondrial respiratory complex I+II state 3 respiration was moderately associated with ABI ($r=0.5$).

CONCLUSIONS

Skeletal muscle arteriole endothelium-dependent vasodilation and mitochondrial respiration are impaired in patients with PAD. Importantly, strong associations for skeletal muscle mitochondrial complex I+II state 3 respiration with ACh-mediated dilation and flow-mediated dilation in skeletal muscle arterioles were noted. This may suggest that microcirculatory dysfunction may strongly negatively impact the skeletal muscle mitochondrial environment. Additionally, there were moderate-to-strong correlations between ABI and both arteriolar endothelium-dependent vasodilatory response and skeletal muscle mitochondrial complex I+II state 3 respiration, which may indicate that increased vascular resistance in the leg is associated with attenuated endothelial and mitochondrial function in the skeletal muscle of PAD patients. In order to establish more comprehensive conclusions, we are currently performing assessments of mitochondrial content, oxidative damage, and angiogenesis of capillaries using PAD tissues.

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ACKNOWLEDGEMENTS

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3D Printed Anatomical Models Improve Student Comprehension of Complex Anatomy: A Systematic Review and Meta-analysis

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Presentation Preference: [**Poster**]

INTRODUCTION

3D printing has had a number of different applications in the medical field, with one of the most recent being the manufacturing of models to replicate anatomical structures [1]. These models can be used to help educate students about various complex anatomical regions such as pelvic bones [2] and organs like the heart [3] and brain [4]. Many articles highlight the potential impact of model usage for educational purposes, however only a limited number of studies have found a way to investigate this idea. The purpose of this study was to perform a systematic review on the current literature and usages of 3D printed models for educational purposes and the impact they have on performance measurements such as assessments and self-perceived education.

METHODS

Based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, 3 databases (Cochrane, Web of Science, and PubMed) were searched using specific search terms and inclusion and exclusion criteria for articles that involved 3D printed anatomical models for student education.

A risk of bias assessment was performed using the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) assessment. A meta-analysis was performed using the randomized control trial experiments on the values of the student assessment. Values that were not presented in percentages were converted based on the total possible score. A random effect size model was used to calculate the pooled effect size of the 7 studies included in the quantitative analysis with a significance value of $p < 0.05$.

RESULTS

From the initial search, 120 potential articles of interest were identified. After duplicates were removed, this number was reduced to 96. After titles and abstracts were reviewed, the number of included articles was reduced to 25. After full-text review, another 11 articles were excluded from the review for lacking a concrete method of evaluation, leaving a total of 14 articles for the qualitative review, and 7 were used for the meta-analysis. 5 of the articles had simple 10-15 questions surveys, and 2 of the assessments included a visualized learning component (i.e. lab practical) as well. The average score for students who used the model across the included studies was 69.103±16.203, and 57.221±15.623 for those who did not ($p<0.001$).

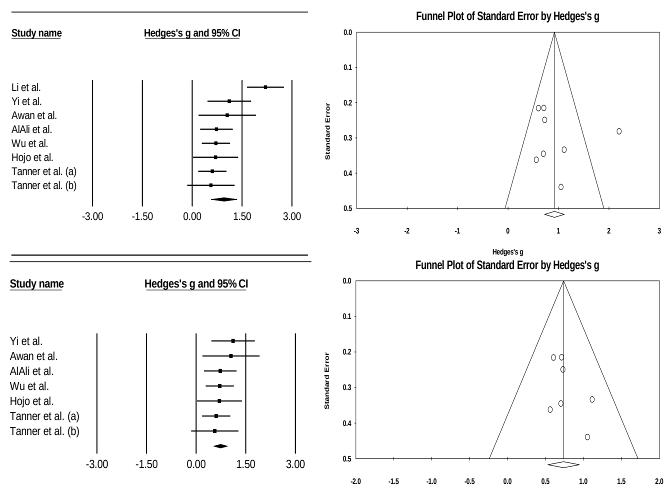

Figure 1: Forrest plot of the Hedge's g values for each study alongside the funnel of the data. Top) Inclusion of the study by Li et al. Bottom) Exclusion of the study by Li et al.

DISCUSSION

The risk of bias assessment revealed the studies included were of average quality, with a range from 12 – 20, and a mean value of 16±2.29. Students who used the 3D printed model as a part of their educational approach performed significantly better than students who did not on objective assessments ($p<0.001$). These results indicate that the use of 3D printed anatomical models have a positive significant impact on education of complex anatomy.

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Table 1: Summary statistics for pooled effect sizes. Analysis 1 includes the Li et al study, while analysis 2 excludes Li et al.

Analysis	**n**	**Mean Δ** (95% CI)	**p**	**Q**	I^2	**Fail-safe N**
Analysis 1	8	0.957 (0.568, 1.346)	< 0.001	26.189	73.271	171
Analysis 2	7	0.738 (0.530, 0.945)	< 0.001	2.42	< 0.001	81

KINEMATIC DIFFERENCES BETWEEN PROFICIENT AND NON-PROFICIENT FREE THROW SHOOTERS

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Presentation Preference: [**Poster**]

INTRODUCTION

While scoring opportunities in basketball can emerge from various sources, free throw shooting has been an elementary contributor for over a century. Previous research found that successful free throw shooting performance accounts for 20-25% of the overall number of scored points and is capable of distinguishing between winning and losing teams [1,2]. Despite its importance, the free throw shooting motion is greatly understudied. Previous research has mainly focused on estimating kinetic and kinematic requirements necessary for achieving optimal ball trajectory and release conditions that ultimately lead to successful free throw outcomes [3,4]. Therefore, the purpose of this study was to examine the difference in kinematic variables between proficient and non-proficient free throw shooters and determine which kinematic variables have the greatest impact on successful free throw shooting performance.

METHODS

Thirteen healthy recreationally active males (height= 187.1±8.2 cm, weight= 89.3±6.7 kg, age= 27.5±6.4 years) shot three sets of ten free throws with 1-2-minute rest between each set. A high-definition camera (Canon PowerShot SX530) recording at 30 fps was used to capture the free throw shooting motion from a sagittal point of view. Video analysis software (Kinovea, Version 0.8.27) was used to analyze the kinematic data. The dependent variables examined in this study are presented in Figure 1. A multivariate Hotelling's T-squared test was used to determine the difference in the dependent variables between a group of proficient and non-proficient shooters. A full-model discriminant function analysis was used to examine the magnitude of the relative contribution of each of the examined variables, as well as to determine the ability to predict between proficient (≥70%; n=8) and non-proficient (<70%; n=5) shooters.

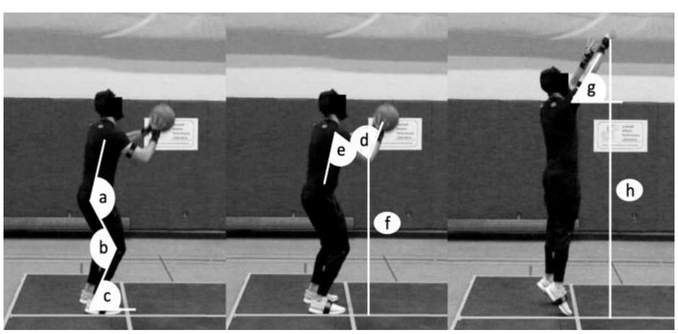

Figure 1: Dependent variables examined in the study. a) internal hip flexion, b) internal knee angle, c) relative ankle flexion, d) internal elbow angle, e) internal shoulder angle, f) relative elbow height, g) relative release angle, and h) relative hand release height.

RESULTS AND DISCUSSION

Mean and standard deviations for kinematic variables examined in this study are presented in Table 1. While all standardized discriminant function coefficients demonstrated moderate to strong magnitudes, the greatest factor in discriminating between proficient and non-proficient free throw shooters were relative elbow height, relative release angle, internal shoulder angle, and relative hand release height variables. By using these kinematic variables to create the discriminant function projection model, 94% of cases were accurately classified as proficient or non-proficient free throw shooters (Table 2).

Table 1. Comparison of kinematic variables between proficient and non-proficient free throw shooters.

Dependent Variable	Proficient (≥70%)	Non-Proficient (<70%)
Internal Knee Angle	101.1 ± 8.1	114.3 ± 5.9 *
Internal Elbow Angle	60.8 ± 7.5	61.1 ± 16.8
Internal Hip Flexion	126.5 ± 14.1	135.6 ± 6.0 *
Relative Ankle Flexion	52.6 ± 3.9	58.9 ± 5.2 *
Relative Release Angle	56.5 ± 6.3	58.6 ± 3.1 *
Internal Shoulder Angle	92.3 ± 19.8	92.6 ± 9.9
Relative Hand Release Height	1.15 ± 0.04	1.13 ± 0.03 *
Relative Elbow Height	0.68 ± 0.11	0.72 ± 0.05 *

**significant difference (p<0.05)*

Table 2. Classification results for predicted group membership.

Actual Group	Predicted group membership		Number of cases
	Non-Proficient	Proficient	
Non-proficient	142 (94.7%)	8 (5.3%)	150
Proficient	10 (6.7%)	140 (93.3%)	150

**94.0% of subjects correctly classified (p<0.05)*

CONCLUSIONS

Based on the findings of this study, we conclude that lower elbow positioning influenced by greater knee, hip, and ankle flexion during the preparatory phase of the free throw shooting motion may lead to improvements in basketball free throw shooting accuracy. Moreover, greater ball release height and release angle values closer to previously estimated standards may decrease the margin of error and aid in further improvements in free throw shooting performance.

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