



**HAL**  
open science

## Relationship between Tactics and Energy Expenditure According to Level of Experience in Badminton

Olivier Dieu, Jérémy Vanhelst, Gilles Bui-Xuân, Thomas Blondeau, Paul Fardy, Jacques Mikulovic

► **To cite this version:**

Olivier Dieu, Jérémy Vanhelst, Gilles Bui-Xuân, Thomas Blondeau, Paul Fardy, et al.. Relationship between Tactics and Energy Expenditure According to Level of Experience in Badminton. *Perceptual and Motor Skills*, 2014, 119 (2), pp.455-467. 10.2466/29.PMS.119c21z3 . hal-04265303

**HAL Id: hal-04265303**

**<https://ulco.hal.science/hal-04265303v1>**

Submitted on 19 Nov 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Ammons Scientific

ORIGINALITY | CREATIVITY | UNDERSTANDING

## Please Do Not Post This Article on the Web!\*

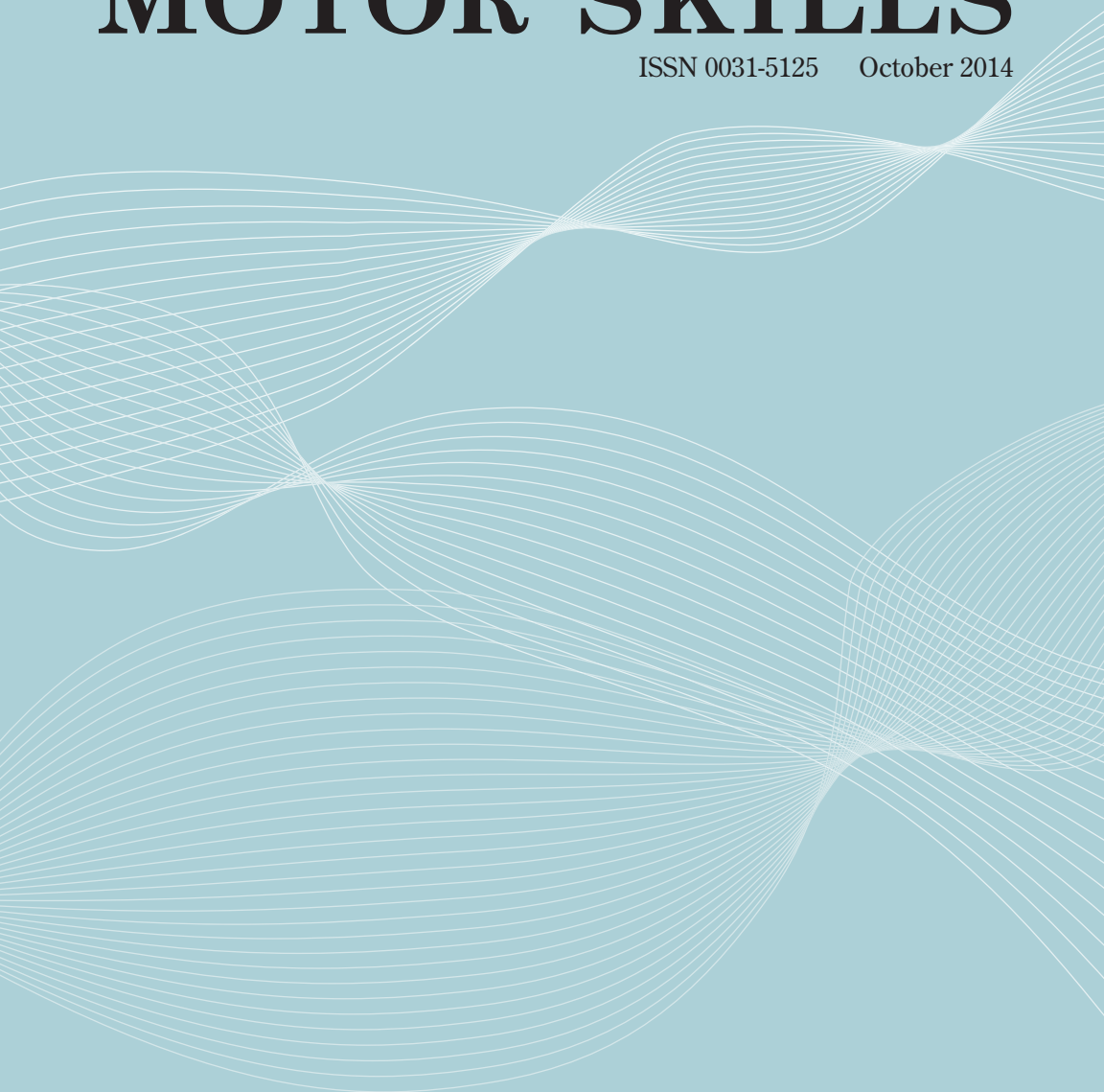
To maintain the [integrity](#) of peer-reviewed and editorially approved publications in *Perceptual and Motor Skills*, Ammons Scientific, Ltd. retains copyright to this article and all accompanying intellectual property rights. Ammons Scientific, Ltd. provides this copy for the author's educational use and research, defined as noncommercial use by the individual author, and specifically includes research and teaching at the author's educational institution, as well as personal educational development and sharing of the article with the author's close colleagues. Any other use, including, but not limited to, reproduction and distribution through paper or electronic copies, posting on any websites, or selling or licensing additional copies is prohibited. This article cannot be used for any commercial purpose whatsoever. [Terms of use](#) are available on the Ammons Scientific website.

\*A code has been embedded in this PDF to allow the publisher to find copies and remind posters about the terms of use.



# PERCEPTUAL & MOTOR SKILLS

ISSN 0031-5125    October 2014



## SECTION 1: EXERCISE & SPORT

<i>Cardiorespiratory Fitness and Hip Bone Mineral Density in Women: A 6-year Prospective Study:</i> LARRY A. TUCKER, NEIL R. NOKES, BRUCE W. BAILEY, AND JAMES D. LECHÉMINANT .....	333
<i>Pick-up of Early Visual Information to Guide Kinetics and Kinematics Within a Group of Highly Skilled Baseball Batters:</i> SEAN MÜLLER, ALEX LALOVIĆ, ALASDAIR R. DEMPSEY, SIMON M. ROSALIE, AND ALLEN G. HARBAUGH .....	347
<i>Constraints of Recreational Sport Participation: Measurement Invariance and Latent Mean Differences Across Sex and Physical Activity Status:</i> JING DONG LIU, PAK KWONG CHUNG, AND WING PING CHEN .....	363
<i>Psychological Skill Model of Collegiate Athletes in Taiwan:</i> KAI LIN AND TZU-CHIN REJOICE CHOU .....	377

## SECTION 2: LEARNING & MEMORY

<i>Effects of Mental Practice in Novice Learners in a Serial Positioning Skill Acquisition:</i> THÁBATA V. B. GOMES, HERBERT UGRINOWITSCH, NÁDIA MARINHO, JOHN B. SHEA, LOUISA D. RAISBECK, AND RODOLFO N. BENDA .....	397
<i>Revisiting the Discussion on the Rationale Underlying the Comparison Question Test:</i> EITAN ELAAD .....	415
<i>Processing Speed in the Aging Process: Screening Criteria for the Spanish Quick Test of Cognitive Speed:</i> JUDIT SUBIRANA-MIRETE, OLGA BRUNA, CARLES VIRGILI, SARA SIGNO, AND CAROLINA PALMA .....	417
<i>Haptic Recognition of Familiar Objects: Examining Lateralization of Specificity Effects:</i> JULIO GONZÁLEZ-ALVAREZ AND MARÍA-ÁNGELES PALOMAR-GARCÍA .....	430

## SECTION 3: MOTOR SKILLS & ERGONOMICS

<i>Effect of Noise Intensity and Illumination Intensity on Visual Performance:</i> CHIN-CHIUAN LIN .....	441
<i>Relationship Between Tactics and Energy Expenditure According to Level of Experience in Badminton:</i> OLIVIER DIEU, THOMAS BLONDEAU, JÉRÉMY VANHELST, PAUL S. FARDY, GILLES BUI-XUÂN, AND JACQUES MIKULOVIC .....	455
<i>Subjective Measures in Sit-to-stand Task in Post-stroke Hemiparesis: Comment on Brière, Nadeau, Lauzière, and Gravel (2013):</i> ANNIE W. Y. NG AND ALAN H. S. CHAN .....	468
<i>Gait Parameters Affecting the Perception Threshold of Locomotor Symmetry: Comment on Lauzière, et al. (2014):</i> WOUTER HOOGKAMER, SJOERD M. BRUIJN, AND JACQUES DUYSSENS .....	474
<i>Self-talk Functions: Portrayal of an Elite Power Lifter:</i> DAVID M. CUTTON AND CHRISTOPHER M. HEARON .....	478
<i>Ballroom Dance and Body Size Perception:</i> CRISTIANE COSTA FONSECA, BIANCA ELISABETH THURM, RODRIGO LUIZ VECCHI, AND ELIANE FLORENCIO GAMA .....	495

## SECTION 4: PERCEPTION

<i>Assimilation Theory Remains a Guidepost for Studying Geometrical Illusions: A Tribute to Alexander Pressey:</i> TED BRUCE JAEGER .....	505
<i>Assimilation Theory, Attention, and Asymmetry in Müller-Lyer Illusions: Quantitative Predictions:</i> ALEXANDER W. PRESSEY .....	509
<i>Using a Generalized Linear Mixed Model Approach to Explore the Role of Age, Motor Proficiency, and Cognitive Styles in Children's Reach Estimation Accuracy:</i> PRISCILA M. CAÇOLA AND MOHAN D. PANT .....	530
<i>Correlates of Implicit Cognitive Line Length Representation in Two-dimensional Space:</i> RICHARD L. DOTY, AJAY KOTI, THOMAS A. O'HARA, JEFFREY LANDY, CHRISTINA SHIN, AND JONATHAN SILAS .....	550
<i>Haptic Perception of Rod Length When Exploration Is Self-determined, Other-determined, and Self-other Co-determined:</i> IN-JO PARK AND JU-IL RIE .....	564

## SECTION 5: PHYSICAL DEVELOPMENT & MEASUREMENT

<i>The Wilderness Novelty Seeking Scale:</i> PIOTR PROCHNIAK .....	577
<i>Effects of Functional Electrical Stimulation on Gait Recovery Post-neurological Injury During Inpatient Rehabilitation:</i> CHAD I. LAIRAMORE, MARK K. GARRISON, LAETITIA BOURGEON, AND MARK MENNEMEIER .....	591
<i>Computerized Assessment of Age Differences in Memory Beliefs:</i> CHRISTOPHER HERTZOG, TARA T. LINEWEAVER, AND JARROD C. HINES .....	609
<i>Physical Self-concept of Adolescents in Western Balkan Countries: A Pilot Study:</i> SNEŽANA RADISAVLJEVIĆ JANIĆ, GREGOR JURAK, IVANA MILANOVIĆ, DUŠANKA LAZAREVIĆ, MARJETA KOVAČ, AND DARIO NOVAK .....	629
<i>Response to Niklasson's Comment on Lin, et al. (2012): "The Relation Between Postural Movement and Bilateral Motor Integration":</i> CHIN-KAI LIN, BOR-CHEN KUO, AND HUEY-MIN WU .....	650
<i>Developmental Timing of the Male-female Health-survival Paradox:</i> THOMAS W. DRAPER AND HAYLEY ABRAHAMSON .....	655

## RELATIONSHIP BETWEEN TACTICS AND ENERGY EXPENDITURE ACCORDING TO LEVEL OF EXPERIENCE IN BADMINTON<sup>1, 2</sup>

OLIVIER DIEU

*UER3S, EA4110, Université de Lille 2,  
Lille, France*

THOMAS BLONDEAU

*Université du Littoral Côte d'Opale (ULCO),  
Dunkerque, France*

JÉRÉMY VANHELST

*Inserm U995, Université Lille 2,  
Lille, France*

PAUL S. FARDY

*Department of Family, Nutrition and Exercise  
Sciences, Queens College  
Flushing, New York*

GILLES BUI-XUÂN

*Université d'Artois, Villeneuve d'Ascq, France*

JACQUES MIKULOVIC

*LACES, EA 4140, Université de  
Bordeaux - ESPE d'Aquitaine*

*Summary.*—Research on racket sports has traditionally focused on expert players and has treated energy expenditure and tactics as independent factors. These prior studies could not assess how energy expenditure and tactics changed as a function of experience and skill. Here, the specific relationship between playing tactics and energy expenditure in badminton were assessed. Participants were classified into five stages of badminton experience on the basis of conative criteria: structural (physical abilities), technical (technical skills), and functional (tactics). The physical activity of 99 players (47 beginners, 15 intermediates, 30 advanced, and 7 experts) was measured using a three-axis accelerometer during a badminton set (21 points, no extra scoring). The results showed that physical activity (counts/sec.) ranged between about 115 (Stage 1) and 155 (Stage 5), and differed significantly across the conative stages. For Stages 2 and 4, defined by an increase in use of tactics, physical activity increased substantially. For Stage 3, defined by a decrease in use of tactics, physical activity decreased significantly. Thus, tactically-oriented play appears to be closely related to physical activity.

A player's physical activity in racket sports, i.e., quantity of body movement (Caspersen, Powell, & Christenson, 1985), has typically been considered from a descriptive standpoint, and measures of it have almost exclusively been limited to top-level players (Hughes, 1994; Majumdar, Khanna, Malik, Sachdeva, Arif, & Mandal, 1997; Faude, Meyer, Rosenberger, Fries, Huber, & Kindermann, 2007; Ooi, Tan, Ahmad, Kwong, Sompong, Ghazali, *et al.*, 2009). Some studies have mainly focused on factors, such as family background, that are unrelated to the changes which occur

<sup>1</sup>Address correspondence to Olivier Dieu, URePSSS- EA 4110, Université du Littoral, Département STAPS, 190 avenue Schumann, 59140 Dunkerque, France or e-mail (olivierdieu@msn.com).

<sup>2</sup>The authors would like to thank the students for taking part in the study. The authors have no competing interests.

in the progression of skill from novice to expert (Lauderdale, Fabsitz, Meyer, Sholinsky, Ramakrishnan, & Goldberg, 1997). Other studies have compared the activity of novices and experts, but they have only considered changes in decisional aspects with increasing technical skills, without evaluating parallel changes in physical activity (McPherson, 2000; Del Villar, García González, Iglesias, Perla Moreno, & Cervello, 2007). As a result, the relationship between changes in physical activity (energy expenditure) and decisional aspects (tactics) as an inherent factor in this progression remains unclear. While energy expenditure and tactics may be seen as relatively independent, both are reported to have a linear progression, i.e., contingent upon the player's expertise, with greater skill corresponding to greater efficiency and increased activity (greater complexity of movement). In tennis, e.g., the study by Del Villar, *et al.* (2007) was aimed at identifying differences between two groups (six expert players from an elite Spanish team and six novice grade school tennis players) in decision-making and execution variables, according to the observation protocol defined by McPherson and Thomas (1989). The authors found that in comparison to novices, "experts required longer exchanges to win the point" (2007, p. 360). This finding appears justified by "the higher skill level of the opposition and by the reduced number of non-forced errors" (2007, p. 362). It would therefore seem that the quantity of body movement increases with expertise. The same authors affirmed the commonly acknowledged notion that novices play by reacting, whereas top-level players play with intent, so the latter exhibit a higher capacity to make good decisions (McPherson, 2000; Del Villar, *et al.*, 2007). McPherson demonstrated for a variety of activities (e.g., 12 experts and 12 novices in baseball, 1993a; expert and novice tennis players from three different age groups, 1999a), with a method based on verbal report analyses of videotape recordings, that top-level players generated more concepts related to "tactical and associated conditions-actions" than did novices (McPherson, 1993a, 1993b, 1999a, 1999b). In contrast, "novices made poor decisions, lacked sophisticated interpretations of conditions, and rarely planned actions" (McPherson, 2000, p. 57). The number and complexity of tactics thus appear to increase with expertise. Studies on badminton tend to support this hypothesis (Limouzin & Wright, 2000; Laffaye, Rivas, & Cabello Manrique, 2001).

Contrary to the above studies, the Majumdar, *et al.* (1997) study looked at the link between the physical and tactical dimensions of badminton. These authors questioned the practice of basing high-level training solely on increased physical activity, emphasizing the technical and tactical specificity of badminton. Their study conducted on six national Indian players, with analyses of 12 training sessions and 35 single matches, found that

players often reported that training sessions were physiologically too intense to be compared with actual game action: "Workouts that are too intense may interfere with coordination, a factor important in sports requiring highly technical skill such as badminton" (1997, p. 342). The quantity of physical activity, then, can affect performance, particularly in "predominantly tactical" sports. This idea could be usefully applied to improving training methods, since it suggests that it is the play that conditions the amount of movement, rather than vice versa.

The conative educational approach (Bui-Xuân, 1999) is based on the idea that tactics or "functionality" are not proportional to expertise. Bui-Xuân suggested that progress in sports is not solely a question of greater efficacy; it also implies a shift in the conative domain, i.e., a shift in the player's intent and mobilization (Bui-Xuân, 1999). Depending on their experience (i.e., "conative stage"), players focus on the game's structural (physical abilities), technical (technical skills), or functional (tactics) aspects. According to Evans (1990), the Conative Educational Model is not consistent with the cognitive approaches mentioned above, where tactics are measured by the player's verbalization of action plans (Kail & Bisanz, 1982) and increase linearly with age and expertise (McPherson & Thomas, 1989). In line with the dynamic and situational aspects, the decision-making thesis (Klein, 1997), Bui-Xuân (1999) defines tactics *in situ* as a shift in the game's direction towards a more functional rather than structural or technical focus.

The conative educational approach is based on a classification that models the meaning assigned to one's own actions (Bui-Xuân, 1999). This model identifies five kinds of *impetus* that guide actions. Impetus is determined by the player's progress through the three components of the model (structural, functional, and technical). The sum of the three components constitutes the "guiding principle" that organizes the five conative stages, which range from novice to expert (Bui-Xuân, 1999). The criteria of the conative classification have been applied already to athletic activity to classify participants in Vanhelst, Beghin, Fardy, Bui-Xuân, & Mikulovic (2012), and more recently in a study on badminton (Dieu, 2012). Table 1 summarizes the criteria and stages used for badminton.

The five conative stages for classifying players from novice to expert are (1) structural, (2) functional, (3) technical, (4) contextual, and (5) expertise. On Stage 1 (structural), the player's intent is to send back the shuttlecock, so physical abilities are mobilized first. Once the player has solved the problem of sending back the shuttlecock, he/she starts to play in the game space to make the opponent move. At this point, the player is already in a "tactical" or functional stage (Stage 2), even if the techniques for acting upon the shuttlecock are basic. On Stage 3 (technical), the player

TABLE 1  
DESCRIPTION OF CONATIVE CLASSIFICATION CRITERIA FOR BADMINTON PLAYER

Conative Stage	Behavior Description	Classifying Indicators	Tactics
Stage 1	The player is the returner. He will return the shuttlecock to the other side of the net regardless of where it lands. The shuttlecock is seen as an obstacle.	Long sending back - central axis.	--
Criterion: Structural		No status differentiation between opponent and defender.	
Conation = Returning the shuttlecock		Only concern: to send to the other side of the net.	
Stage 2	The player is the distributor. He places the shuttlecock on the other side of the net. He will search the free space.	Trajectory variations.	++
Criterion: Functional		The opponent runs after the shuttlecock. He tries to send it to the side where the opponent isn't standing.	
Conation = Directing the shuttlecock			
Stage 3	Technical application (smashing). The player places the shuttlecock but does not re-position him/herself after hitting.	Release or smash in attack.	-
Criterion: Technical		Pause in re-positioning to observe the result of one's action.	
Conation = Making a winning stroke			
Stage 4	Technical-tactical sequence. The player develops tactical plans, strategies of attack and defense.	Re-positioning directed after the hitting (sequence).	++
Criterion: Contextual		Playing in interception.	
Conation = Tactical sequence			
Stage 5	This stage is represented by expertise in practice.	Mobilizes his/her own structure and techniques according to his/her own playing style.	++
Criterion: Expertise			
Conation = Force your game on the opponent			

Note.—“Tactics”: increase in use of tactics (+), major increase (++), decrease in use of tactics (-), major decrease (--).



loses in functionality what he/she gains in technical efficiency, since this is a stage of stabilization of the driving skill (Schmidt, 1988). It is not until the next level (Stage 4) that the player is able to "contextualize" his/her technique in a sequence of strokes, so this stage is tactical again. The highest or expert stage (Stage 5) is characterized by optimal mobilization of the structural, functional, and technical abilities to form one's playing style.

Bui-Xuân showed that tactics, as defined above, are a characteristic of Level 2, a functional stage; tactics decreases in Level 3, a technical stage, and then become a priority once again in Level 4, a contextual stage. According to Abernethy, Thomas, and Thomas (1993), this idea is potentially compatible with the cognitive approach. As early as 1993, these authors speculated that novices might resort to some kind of tactical activity, but suggested that this activity would likely be of a different nature because "experts used different cues in sport solving situations" (Abernethy, *et al.*, cited by McPherson, 1993b, p. 320). In the current account based on the conative model, this specific relationship between playing level and tactics is the basis of the hypothesis:

*Hypothesis.* Physical activity, as measured by an accelerometer, will differ significantly across the conative stages, particularly in Stages 2 and 4, in which participants are predicted to make greater use of tactics.

## METHOD

### *Participants*

Ninety-nine healthy adults participated in the study. They were volunteer students or federal league badminton players in France. There were 62 men ( $M$  age=21.3yr.,  $SD$ =5.0;  $M$  height=178.3cm,  $SD$ =6.4;  $M$  weight=74.5kg,  $SD$ =9.7) and 37 women ( $M$  age=20.4yr.,  $SD$ =3.9;  $M$  height=166.1cm,  $SD$ =6.2;  $M$  weight=59.4kg,  $SD$ =7.7). Participants played several sets against various opponents. All players were videotaped and classified into one of five stages on the basis of conative criteria (Table 1). The data to be saved for analysis could not be selected in advance. Given the desire for balanced opposition, it was the score of the set played that dictated whether the data should be retained. Matches where the loser's score was below 11 points were discarded.

### *Measures*

*Anthropometric measures.*—Each participant was weighed without shoes or heavy outer garments to the nearest 0.1 kg, using an electronic scale (Oregon Scientific GA101, Portland, OR, USA). Height was measured without shoes to the nearest 0.1 cm using a standard physician's scale.

*Conative stages.*—The participants were observed and classified into a conative stage: (1) structural, (2) functional, (3) technical, (4) contextual, and (5) expertise, according to the criteria given in Table 1. The theoretical conative classification (Table 1) was validated using a video test given to the 10 badminton specialists who made up the jury for the national competition used in 2011 to recruit physical education teachers in France. This interactive test has two phases: a video presenting the conative classification for badminton (conative stage and macroscopic indicators for each stage) and 16 videos for which the juries have to circle the stage shown in the video and choose the corresponding indicator. The validity rate of the test is satisfactory since it revealed a 5% error margin for juries differing in age, region of France, and initial training. Moreover, unlike the jury, which had only six minutes of viewing time, for this study lengthy observations were used, supplemented by video recordings. This brought out one or more new observations *a posteriori* and allowed elimination of any videos that could potentially be interpreted differently. If any “macroscopic” indicators were spotted during these preliminary observations, the individual was put into the corresponding stage. During the measurement phase, the two players playing against each other were always at the same stage, so that an accurate evaluation of their skills and stage could be made (e.g., an expert played against another expert).

*Measuring physical activity.*—All participants wore a three-axis accelerometer (GT3X, ActiGraph, Pensacola, FL, USA) for every set they played (21 points, no extra scoring). The only instruction was to play normally. Physical activity was measured by the ActiGraph accelerometer. Accelerometry technology is based on mechanical principles. An accelerometer consists of a piezoelectric element and a seismic mass, and measures acceleration. Acceleration is defined as a change in velocity over time; it quantifies the quantity and intensity of a movement. When the participant moves, the sensor detects acceleration, and the seismic mass causes the piezoelectric element to experience deformation in the form of bending, direct tension, or compression. These conformational changes cause a build-up of a displaced charge on one side of the sensor, which generates a variable output voltage signal, i.e., proportional to the applied acceleration. The voltage signal, after being filtered and amplified, is then sampled at a prefixed frequency by the device, which converts the analog voltage signal to a digital series of numbers, called “counts” (Chen & Bassett, 2005). The GT3X accelerometer recorded movements in three dimensions: vertical vector (x), anteroposterior vector (y), and mediolateral vector (z). The vector magnitude (VM) is the square root of the sum of activity counts squared in each vector.



FIG. 1. Position of the ActiGraph on the participant

The GT3X accelerometer was calibrated according to the manufacturer's specifications. The epoch interval used was set at 1 sec., and output was expressed as the mean number of counts per second. Each participant was monitored during each game played. The accelerometer was attached to a belt at the height of the participant's back (Fig. 1). Data were uploaded from the monitor to a computer after the testing period.

### *Design*

The study took place between January 13 and April 26, 2011. At the beginning of the part of training during which the measures were taken, players deemed to belong to the same conative stage were informed of the possibility of participating in a study on badminton (so as not to affect the internal validity of the study, the use of the conative approach was not explained). Volunteers were given a letter of information and a consent form. The protocol was as follows: (1) Play a 21-point badminton set (with no extra scoring and no half-time break) against an assigned opponent. (2) Wear an actimetric belt equipped with a GT3X ActiGraph (with the device positioned at the height of the lumbar spine). (3) Agree to be filmed. To reduce the effects of the equipment, at the beginning of the session the camera was placed behind the court so as to demystify its presence. See Table 2 for details.

TABLE 2  
NUMBER OF SETS PLAYED, BY CONATIVE STAGE

	Sets	Men	Women
Structural stage	40	9	31
Functional stage	40	25	15
Technical stage	40	31	9
Contextual stage	40	32	8
Expertise stage	40	34	6

### Statistical Analysis

Data management and analysis were performed using Excel 2003 (Microsoft, Inc., Redmond, WA, USA) and the Statistical Package for the Social Sciences (SPSS) for Windows, Version 11.5 (SPSS, Inc., Chicago, IL, USA). Analysis of variance (ANOVA) was used to compare physical activity between the conative stages. Statistical significance was set at  $p < .05$ .

### RESULTS

The accelerometer data means for the three axes and for the vector magnitude (in counts per second) are shown in Table 3. The results showed that physical activity (counts/sec.) ranged between about 115 (Stage 1) and 155 (Stage 5) and differed significantly across the conative stages. A 13% increase in the mean between the structural and functional stages was observed (Fig. 2), followed by a 3% decrease at the technical stage. There was another clear-cut increase (+22%) between the technical and contextual stages. Finally, a 1% increase in the mean was observed between the contextual and expertise stages.

TABLE 3  
MEAN COUNTS FOR EACH CONATIVE STAGE WITH COMPARISONS ACROSS STAGES

Accelerometer Axis		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	<i>F</i>	<i>p</i>	$\eta^2$
X axis	<i>M</i>	67.1	76.2	74.7	97.9	92.0	9.26	<.01	0.93
	<i>SD</i>	11.7	11.0	9.1	18.9	8.5			
Y axis	<i>M</i>	56.1	61.8	61.0	71.9	79.7	8.16	<.05	0.90
	<i>SD</i>	10.7	10.9	9.3	13.0	8.2			
Z axis	<i>M</i>	60.0	70.0	66.2	76.4	77.9	9.78	<.05	0.91
	<i>SD</i>	8.0	8.1	7.4	9.0	6.8			
VM	<i>M</i>	114.7	129.7	125.5	153.1	154.7	9.89	<.001	0.95
	<i>SD</i>	13.2	14.4	11.7	21.2	9.9			

Note.—VM = vector magnitude, the square root of the sum of activity counts squared in each axis;  $\eta^2$  is the effect size.

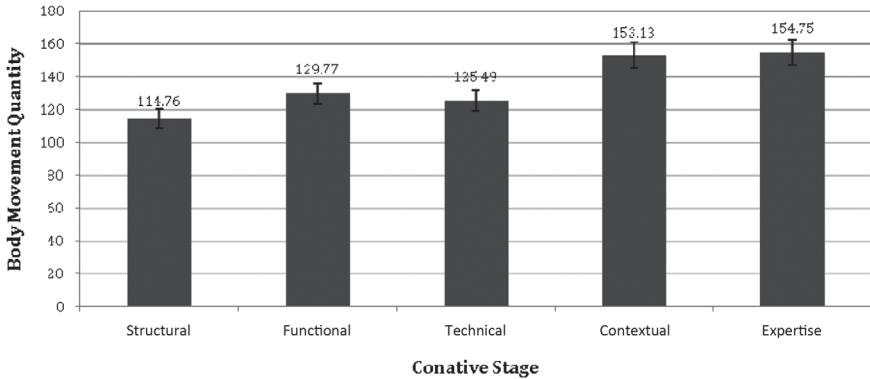


FIG. 2. Body-movement quantity (VM mean in counts/sec.) by conative stage

#### DISCUSSION

Traditionally, studies of physical activity have focused solely on expert players (Cabello Manrique & Gonzalez-Badillo, 2003; Carlson, Tyrell, & Naughton, 1985; Ooi, *et al.*, 2009), and they have relied on an invasive methodology: measuring the blood lactate level (Ghosh, Majumbar, Goswami, Ahuja, & Puri, 1990; Ghosh, Goswami, & Ahuja, 1993; Novas, Rowbottom, & Jenkins, 2003). This study is one of the first to use accelerometry to compare the physical activity of badminton players across a broad range of skill levels, from novice to expert.

In the research on racket sports, energy expenditure and decisional aspects have tended to be treated as largely independent factors. It is commonly accepted that a rise in expertise results in a linear increase in physical activity (Del Villar, *et al.*, 2007) and in tactical activity (McPherson, 1993a, 1993b, 1999a, 1999b, 2000). However, this is not the only possibility, and to test an alternative approach this study was based on the conative model, where acquiring experience in badminton is represented as a series of separate conative stages. This approach seems like an interesting alternative because it suggests a more qualitative description of the changes in the physical activity of badminton players as they progress from novice to expert. Each stage entails focusing on new structural, functional, and/or technical aspects, based on what the player mobilizes as he/she plays. The results suggest that depending on the conative stage, body-movement quantity varies in an irregular, non-linear manner.

The results indicated that at Stage 1, where the focus is structural, the players concentrated on returning the shuttlecock, with the intention of hitting it as hard as possible over to the other side of the net, with little body movement. At Stage 2, where the focus is functional, the players started to aim at empty spaces, although their technical skills were still limited. For ex-

ample, one player first hit the shuttlecock to the right side of the court, then to the left side, which caused the opponent to run after the shuttlecock; this resulted in a large increase in physical activity. At Stage 3, where technical aspects gradually increased and players focused on the execution of strokes (they paused after a hit), they tended to move less, so the physical activity level decreased. At Stage 4, where the focus was both technical and functional, the players changed their tactics to fit the context. Their goal was to outpace their opponent. For example, the player intercepted with a jump, and then rushed to the net. At this stage, the players increasingly attempted to create a difficult situation so the opponent would make an error. They used both space and time, and mobilized themselves in a flexible, dynamic fashion. This stage showed another large increase in physical activity. In Stage 5, where structural, functional, and technical aspects are more balanced, the physical activity level increased but not as much as in Stages 2 and 4.

In this model, physical activity differs significantly across stages defined by the conative classification. In Stages 2 and 4, physical activity increased substantially; these two stages, which are functional and contextual, are defined by an increase in the use of tactics. However, they differed in the nature of the player's intent; i.e., space-oriented on Stage 2, but both space- and time-oriented at Stage 4. Thus, player mobilization reaches its highest level during the stages that reflect the guiding principle (Bui-Xuân, 1999; Vanhelst, *et al.*, 2012) of badminton: a score-based activity where the winner does not necessarily have better structural skills (as in a running sprint) or better technical skills (as in gymnastics), but manages to outplay the opponent (tactical aspect). For this reason, there should not be a linear relationship between the amount of body movement and expertise. The former is not proportional to the latter.

This alternative model of progression emphasizes that the nature of the players' activity changes radically as he/she progresses through the conative stages, and that these changes depend on the intent behind the action (Bui-Xuân, 1998). The hypothesis was supported: among these badminton players, there were significant differences in physical activity across the conative stages, particularly in Stages 2 and 4, marking the greater use of tactics. Physical activity did not seem to depend so much on expertise, but rather on how much progress the players had made toward greater functional mobilization (tactical focus). To increase on-court body movement in badminton, teaching methods should therefore be based on the activity's guiding principle (scoring) rather than on simply "shadowing" artificial situations, a training method in badminton that consists of rehearsing movements on the court with no shuttlecock or opponent (Laffaye, 2011).

#### *Limitations and Conclusions*

There were several limitations. First, there were nearly twice as many men as women, and possible effects of age and sex on the amount of body

movement were not taken into account here. According to other studies, there are sex differences in game intensity, especially in tennis (Fernandez, Mendez-Villanueva, & Pluim, 2006).

In summary, the badminton players' physical activity was not significantly associated with their expertise. If these results can be generalized, then they suggest that greater importance should be placed on the intent in the game rather than solely on increasing physical activity. In the schools, rather than seeking only to increase the student's quantity of body movement, teaching strategies should be focused on taking into account how students mobilize themselves to meet their current goal, in accordance with their current conative stage. During the learning period, encouraging an increase in body-movement quantity is not recommended either, since the player's mobilization is dictated by the playing level itself. It would be better to address tactical aspects and physical training jointly, since a player's experience shows that these two facets are connected. In future research, accelerometry could be used to assess the ergonomic specificities of each conative stage: the player's positioning in space and time management during play.

#### REFERENCES

- ABERNETHY, B., THOMAS, K., & THOMAS, J. (1993) Strategies for improving understanding of motor expertise (or mistakes we have made and things we have learned!). In J. L. Starkes & F. Allard (Eds.), *Cognitive issues in motor expertise*. Amsterdam, The Netherlands: Elsevier. Pp. 317-356.
- BUI-XUÂN, G. (1999) Modeling process teaching. In G. Bui-Xuân & J. Gleyse (Eds.), *Teaching physical education*. Clermont-Ferrand, France: AFRAPS. Pp. 79-96.
- CABELLO MANRIQUE, D., & GONZALEZ-BADILLO, J. J. (2003) Analysis of the characteristics of competitive badminton. *British Journal of Sport and Medicine*, 37(1), 62-66.
- CARLSON, J., TYRELL, J., & NAUGHTON, G. (1985) Physiological responses during badminton games by elite Australian players. *Badminton Sitelines*, 13, 17-20.
- CASPERSEN, C. J., POWELL, K. E., & CHRISTENSON, G. M. (1985) Physical activity, exercise and physical fitness: definitions and distinctions for health-related research. *Public Health Reports*, 110, 126-131.
- CHEN, K. Y., & BASSETT, D. R. (2005) The technology of accelerometry-based activity monitors: current and future. *Medicine & Science in Sports & Exercise*, 37, 490-500.
- DEL VILLAR, F., GARCÍA GONZÁLEZ, L., IGLESIAS, D., PERLA MORENO, M., & CERVELLÓ, E. M. (2007) Expert-novice differences in cognitive and execution skills during tennis competition. *Perceptual & Motor Skills*, 104(2), 355-365.
- DIEU, O. (2012) Physical experiment and senses of the movement: concretization via actimetry of the "context distorted by the action" in the evolution of the badminton player. *The International Journal of Sport Science and Physical Education*, 98, 49-65.
- EVANS, J. (1990) Verbal reports of cognitive strategies: a note on Marques and Pereira. *The Quarterly Journal of Experimental Psychology*, 42, 169-170.
- FAUDE, O., MEYER, T., ROSENBERGER, F., FRIES, M., HUBER, G., & KINDERMANN, W. (2007) Physiological characteristics of badminton match play. *European Journal of Applied Physiology*, 100(4), 479-485.

- FERNANDEZ, J., MENDEZ-VILLANUEVA, A., & PLUIM, B. M. (2006) Intensity of tennis match play. *British Journal of Sports and Medicine*, 40(5), 387-391.
- GHOSH, A. K., GOSWAMI, A., & AHUJA, A. (1993) Evaluation of a sports specific training programme in badminton players. *Indian Journal of Medical Research*, 98, 232-236.
- GHOSH, A. K., MAJUMBAR, P., GOSWAMI, A., AHUJA, A., & PURI, T. P. S. (1990) Heart rate and blood lactate response in competitive badminton. *Annals of Sport Medicine and Research*, 5(2), 85-88.
- HUGHES, M. G. (1994) Physiological demands of training in elite badminton players. In T. Reilly, M. Hughes, & A. Lees (Eds.), *Science and racket sports*. London, UK: E. & F. N. Spon. Pp. 32-37.
- KAIL, R. V., & BISANZ, J. (1982) Cognitive strategies. In C. R. Puff (Ed.), *Handbook of research methods in human memory and cognition*. New York: Academic Press. Pp. 229-255.
- KLEIN, G. (1997) The current status of the naturalistic decision making framework. In R. Flin, E. Salas, M. E. Strubet, & L. Martin (Eds.), *Decision making under stress: emerging themes and applications*. Aldershot, UK: Ashgate. Pp. 11-28.
- LAFFAYE, G. (2011) *Understanding and progressing in badminton*. Magny-Les-Hameaux, France: Chiron.
- LAFFAYE, G., RIVAS, F., & CABELLO MANRIQUE, D. (2001) The role of visual information in the training of badminton players: informative curricula. *IV IBF World Coaches Conference*. Seville, Spain, May 31-June 2. Pp. 327-345.
- LAUDERDALE, D. S., FABSITZ, R., MEYER, J. M., SHOLINSKY, P., RAMAKRISHNAN, V., & GOLDBERG, J. (1997) Familial determinants of moderate and intense physical activity: a twin study. *Medicine & Science in Sports & Exercise*, 29(8), 1062-1068.
- LIMOUZIN, P., & WRIGHT, I. (2000) *Badminton: progressing toward the highest level*. Paris, France: Insep Diffusion.
- MAJUMDAR, P., KHANNA, G. L., MALIK, V., SACHDEVA, S., ARIF, M., & MANDAL, M. (1997) Physiological analysis to quantify training load in badminton. *British Journal of Sports Medicine*, 31(4), 342-345.
- MCPHERSON, S. L. (1993a) Knowledge representation and decision making in sport. In J. L. Starkes & F. Allard (Eds.), *Cognitive issues in motor expertise*. Amsterdam, The Netherlands: Elsevier. Pp. 159-188.
- MCPHERSON, S. L. (1993b) The influence of player experience on problem solving during batting preparation in baseball. *Journal of Sport and Exercise Psychology*, 15, 304-325.
- MCPHERSON, S. L. (1999a) Expert-novice differences in performance skills and problem representations of youth and adults during tennis competition. *Research Quarterly for Exercise and Sport*, 70, 233-251.
- MCPHERSON, S. L. (1999b) Tactical differences in problem representations and solutions in collegiate varsity and beginner women tennis players. *Research Quarterly for Exercise and Sport*, 70, 369-384.
- MCPHERSON, S. L. (2000) Expert-novice differences in planning strategies during collegiate singles tennis competition. *Journal of Sport and Exercise Psychology*, 22, 39-62.
- MCPHERSON, S. L., & THOMAS, J. R. (1989) Relation of knowledge and performance in boys' tennis: age and expertise. *Journal of Experimental Child Psychology*, 48, 190-211.
- NOVAS, A. M., ROWBOTTOM, D. G., & JENKINS, D. G. (2003) A practical method of estimating energy expenditure during tennis play. *Journal of Science and Medicine in Sport*, 6(1), 40-50.



- Ooi, C. H., TAN, A., AHMAD, A., KWONG, K. W., SOMPONG, R., GHAZALI, K. A., LIEW, S. L., CHAI, W. J., & THOMPSON, M. W. (2009) Physiological characteristics of elite and sub-elite badminton players. *Journal of Sports Sciences*, 27(14), 1591-1599.
- SCHMIDT, R. A. (1988) *Motor control and learning: a behavioral emphasis*. (2nd ed.) Champaign, IL: Human Kinetics.
- VANHELST, J., BEGHIN, L., FARDY, P., BUI-XUÂN, G., & MIKULOVIC, J. (2012) A conative educational model for an intervention program in obese youth. *BMC Public Health*, 12, 416.

*Accepted August 12, 2014.*