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Injury Prevention Effects of a Ballet Basics Training Program*

– Biomechanical Analysis of the Participants' Experience from the Program –

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I. Introduction

Ballet dancers become immersed in repetitive practice for many hours from childhood, and even after becoming professional dancers, they become immersed in countless rehearsals and performances for a long time. In the process, excessive turnouts and prolonged physical activity beyond anatomical limits cause ballet dancers to suffer from frequent injuries or chronic pain (Sojung Jang, 2022). In particular, repeated training of physical and artistic skills required by ballet while maintaining incorrect body alignment may lead to spinal diseases or imbalance in the pelvis. For ballet dancers, balance and stability of posture are essential to hold out, rotate, and leap on one leg while maintaining a good center of gravity. Since ballet requires controlled movements and requires a moment of pause at the same time, excellent posture control is required to perform successful movements. However, ballet requires excessive turn-out or rotation of one axis compared to other genres of dance or physical activity. Variation in classical ballet has many turns and jumps that is supported with one leg and often use the other leg. Therefore, lateral bias, in which only one leg develops excessively, causes tension and stress, which leads to chronic pain or injury (Mertz and Docherty, 2012).

This study is conducted to establish a theory and hypothesis that even a basic ballet training program can improve body balance and posture control to prevent injury, and to develop a training

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program corresponding to it to verify its effect through biomechanical analysis and qualitative investigation. In order to achieve this research purposes, this study consists of the following contents. First, Chapter II establishes a theoretical framework that theoretically proves the effectiveness of the ballet basics program by reviewing previous studies arguing that maintaining body balance is a key causal variable in preventing ballet injuries. Chapter III describes the ballet basics program, so-called PRS program, developed based on three basic ballet movements: *Plié, Relevé-demi point*, and *temps levé Sauté*, and how to collect and analyze biomechanical data after training 10 college ballet majors for 8 weeks for experimental purposes. In addition, it explains the method and reason for collecting qualitative data by conducting an interview survey on the subjects. Next, Chapter IV provides statistical analysis of biomechanical data, as well as results and implications with supplemental qualitative analysis results. Finally, in Chapter V, conclusions are discussed.

II. Theories on Body Balance and Injury Risk

1. Causal mechanism of ballet injury: Literature review

The movements required in ballet often involve movements beyond anatomical limits of human body such as turnouts and points, and ballet is recognized as an activity that requires a higher physical burden than any other sports (Kenny, Whittaker and Emery, 2016; Watkins et al., 1989). A rigorous training process for honing dance styles that require high levels of physical and artistic skill exposes dancers to the risk of musculoskeletical injuries (Kenny, Whittaker and Emery, 2016). A study by Kadel (2006) reveals that 17% to 24% of modern dancers are experiencing injuries, while 67% to 95% of ballet dancers are experiencing injuries. Watson et al. (2017) reported that 82% of vocational modern dancers in the United States have experienced injuries within the past 12 months, while this rate for vocational ballet dancers reaches 95%.

This study focuses on body balance or postural stability as a key cause variable of injury risk that can occur to ballet dancers[1]. Body balance, posture stability, posture alignment, posture control, posture balance, etc. are all closely interrelated and all define similar concepts. For example, according to Bruyneel (2010), the concept of 'posture' refers to a position linked to the composition of a set of body parts at a given point in time and is defined as being controlled by the musculoskeletal system. On the other hand, the concept of 'postural stability (PS)' refers to 'the ability to maintain the center of gravity against the base of support (BOS)', according to Lin et al. (2011), while the concept

1) As similar terms in this regard, concepts such as body alignment, postural alignment, postural balance, and postural control have been dealt with as causes of ballet injury in several previous studies, and are understood as concepts similar to body balance or posture stability.

of balance refers to ‘the process of maintaining posture stability“. There are many previous studies that verified the fact that these concepts play an important role as the key causal factor of injuries experienced by ballet dancers.

Kenny, Whittaker and Emery (2016) synthesized 47 studies on the causes of musculoskeletal injuries in professional dancers using qualitative synthesis method. They reported body alignment, specifically lower extremity alignment or ‘the inclination of sacrum at a turn-out angle of more than 30 degrees’, as the main cause of musculoskeletal injury, along with other psychological factors such as past injury experiences, negative stress or perfectionism, and physical factors such as body mass index (BMI) or body fat (BF). Another study that identified lower extremity alignment as the main cause of injury was done by Watkins et al. (1989). This study measured the knee-foot alignment angle of 22 young (under 13) dance majors, 171 aspiring professional dancers, 58 dance majors, and 99 professional dancers and studied their relationship to injuries. Their study found that young dancers had the greatest angle of departure from the center axis compared to other groups, so they tended to force the turn-out posture from their ankles and consequently increased the risk of injury by applying inappropriate stress to their knees.

There are also studies suggesting balance and postural stability, which are similar concepts to postural alignment, as the main causes of injury. A representative study by Lin et al. (2011) compared posture stability in 33 ballet dancers, and explained that ballet requires a high level of balance control ability to perform extreme range of movements (e.g., extensive ankle under flexion, extreme hip extension). Flexibility alone is not enough to perform an extreme range of joint movements, but balance control is also required. If this is not done properly, ballet dancers are exposed to the risk of injury.

The mechanism by which lack of body balance or posture stability lead to injury has also been explained by a number of previous studies. Watkins et al. (1989) relates the concept of lower extremity alignment to an indispensable turn-out motion for a successful ballet dancer’s career explaining that if the lower extremity alignment is properly achieved, the turn-out occurs at the hip and the knees are aligned close to the center of the foot. According to Watkins et al. (1989), if the range of extrapolation of the hip socket is limited, the ballet dancer tends to perform a so-called ‘compensation movement’ that makes the dancer incorrectly turns out at the knee or ankle, but not at the hip joint. This excessive compensation movement makes the knee to end up being aligned far ahead of the medial border of the foot. Watkins et al. explains that a number of medical experts point out that this incorrect turn-out behavior causes twisting of the musculoskeletal structure, causing chronic injuries to lower extremities such as knees, ankles, and feet. Bowerman et al. (2015) pointed out that abnormal alignment of hips, knees, and ankles is a major risk factor for lower extremity injuries, emphasizing that incorrect alignment can lead to decreased function and increased discomfort. Like Watkins et al.'s study, Bowerman et al. explains that turn-out is a key component of ballet skills, and muscle strength, soft tissue extensibility, and skeletal anatomical factors are needed to properly perform this. If a dancer's range of movements is limited, it is known that the dancer's kinetic chain operates the compensation strategy to perform the turn-out movement. It is explained that if this compensation action occurs at an anatomical point, not at a hip joint, in other words, if lumbar lordosis, pronation of the foot, and ablation of the forefoot occur, dancers are exposed to a very large risk of injury.

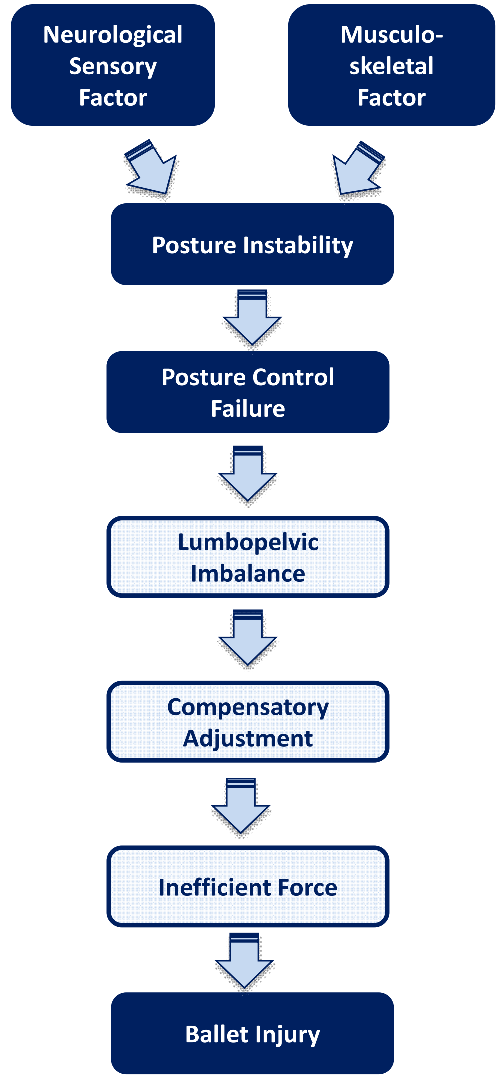
A study by Ambgaonkar et al. (2012) also describes inefficient compensation behavior as a major mediating mechanism in which posture instability leads to injury. Their study explains that core stability is a major factor for the prevention of injuries to ballet dancers, and that if any of the active, passive, or neural control system components that make up core stability are deficient, the balance of the lumbar pelvis will collapse before the total movement of the surrounding area. This explains that instability in the lumbar pelvis causes compensatory adjustment of the torso and lower limbs, which in turn leads to inefficient physical force and injury.

2. Principle of injury prevention of basic ballet movements

The principle that the ballet basics program to be developed, experimented, and analyzed in this study can reduce the risk of injury is to intervene in the 'causal factor' that determines body balance or posture stability to strengthen correct body alignment and posture stability. The rationale for giving logical justification to the prediction that the ballet basic skills program can reduce the injury risk can be found in the theoretical model of the causal mechanism that explains the causal relationship between 'body balance or posture stability and injury risk' shown in the figure below (Sojung Jang, 2022). This model was constructed by synthesizing the previous studies discussed above.

As shown in the figure, 'compensation behavior' or 'compensatory adaptation behavior' acts as a key mediator in the mechanism by which posture stability reduces the risk of injury or posture instability increases the risk of injury. As discussed in studies such as Watkins et al. (1989), Bowerman et al. (2015), Ambegaonkar et al. (2012), Deckert, Barry and Welsh (2007), when the body alignment or posture balance is broken due to the underdevelopment of the nervous system, the scope of exercise is limited to be performed. Nevertheless, when trying to perform the required movement, the compensation strategy starts to work in the dancer's kinetic chain. If this compensation action occurs at an anatomical point other than the hip joint, it leads to a back or lower extremity injury. Therefore, the causal necessary condition for the ballet basic skills program to be effective will be to cultivate the physical ability of ballet dancers to perform the basic movements of ballet without accompanying compensation movements.

The ballet basic skills program developed in this study is centered on the plié movement, which is the source and foundation of power in all dance movements (Geumran Park, 2007). Plié is known to help develop muscles such as the Achilles tendon flexibility and strength (Roach, 1997) and develop muscles such as the thigh, abdominal muscles, and feet (Muriel, 1984). In addition, plié maintains the body's verticality in the relevé, which is the basis of rotation movement, has a profound effect on the speed control of rotation (Sangyeon Kim, 2005), and acts like a spring from the moment of leap to the moment of landing on the ground when performing the sauté (Muriel, 1984). When the plié is efficiently performed, the center of gravity is not carried on the legs, thereby minimizing tension in the lower body and allowing the feet to be placed comfortably on the floor (Minton and Solomon, 1990). It is also known to develop flexibility of the knee and develop a sense of balance in the body because it helps the perception of muscles by the vertical principle of the spine (Geumran Park, 2007). This functional principle of plié enables the prediction that the ballet basic skills program experimented in this study will enhance body balance and lower extremity muscle strength, thereby controlling compensation movements and reducing the risk of injury.



<Figure 1> Theory on causal mechanism of ballet injury

The prediction that the ballet basic skills program will have the effect of improving posture stability or body balance can also be found in plié's anatomical principle. Plié's hip flextion must maintain a neutral position of the pelvis, and hip flexion causes knee flexion and ankle joint back flexion. Muscles that flex the hip joint include iliopsoas, sartorius, tensor fasciae latae, and rectus femoris, of which the main muscle used in plié is iliopsoas (Eunji Kim, 2014). The iliopsoas is a muscle that controls the femoral nerve and the action of flexing the femur in the hip joint (Stone, 2003). In addition to flexing the hip joint, the iliopsoas performs an important function as a postural muscle. It is known to maintain pelvic stability because the iliac root connects the lower lumbar spine and thigh of the spine and passes through the hip joint (Eunji Kim, 2014). Therefore, the iliopsoas is said to play a major role in stabilizing the muscles of the hip joint (Sweigard, 1974), straightening the body, and connecting the center of gravity to the pelvis and legs through the spine (Todd, 1937). In addition, iliopsoas is a hip bending muscle for ballet dancers, and is known to play an important role in maintaining the main movement of ballet, such as plié, rond de jambe which lift or rotate the legs in the air, battement relevé lent, *battement de dévelopé*, and *grand battement*.

In addition, one can also find quite a few previous studies that directly suggest the injury prevention effect of basic ballet technique training. According to a study by Bruyneel et al. (2011), ballet basic training improves flexibility, muscle strength, and balance, improving the quality and speed of responding to imbalances, and further optimizing movement balance and minimizing the risk of injury by training dancers' unique susceptibility. The Rein et al. (2011) study also found that ballet dancers' posture control and functional stability of the feet and ankles are greatly influenced by proprioceptive influences, which can be improved through regular ballet training.

III. Research Methods

1. Developing the ballet basics program

The aim of this study is to develop a physical training program composed only of basic ballet techniques, and test whether it actually helps improve postural stability of ballet dancers thus lower the risk of injury. In addition to the functional and anatomical reasons discussed above, some practical reasons are contained in the reasons why the training program to be developed in this study is composed of only basic ballet techniques. Although there are many preceding studies that develop training programs and biomechanically analyze their effects, most studies focus on training methods using Pilates or other small tools (e.g., Kyungmi Lee, 2014; Jiyoung Kwon, 2016; Minsun Park, 2019). However, as Kadel (2006)'s study points out, it is practically difficult for ballet dancers suffering from harsh rehearsal schedules, long performance times, intensive summer training programs, frequent classes, and rehearsal times to participate in separate training programs that require separate tools and facilities. On the other hand, the program developed in this study has a practical superiority in that it can be conveniently carried out as a concept of a finishing exercise without the help of a separate tool or facility, and as an extended session of the regular class. Moreover, a training program that immediately corrects disorganized body alignment may be more useful because ballet classes in reality require more frequent right leg movements or more frequent right leg expressions at the beginning of barre and center combination, instead of training two legs in balance, thus frequently lead to lateral bias.

The ballet basics program (hereinafter referred to as the PRS program) to be developed and tested in this study consists of three basic ballet movements: *Plié, Relevé-demi point*, and *temps levé Sauté*. The PRS program was conducted after students' daily classes and rehearsals were all completed as a concept of finishing program. In the PRS program, subjects hold the bars with both hands for intensive training. In typical situations, rehearsals of ballet works are often choreographed to use only one side of the body. Therefore, a finishing program like the PRS program that corrects lateral bias and body imbalance during practice is essentially required, and the PRS program aims to improve body balance and posture stability by developing musculoskeletal functions and sensory nervous system functions while maintaining dancer's ability to cope with injury. The table below summarizes the detailed configuration and methods of the PRS program.

<Table 1> Configuration and Methods of the PRS Program

Configuration: Total 50 min.	Methods		
Warming up 5 min.	Warm up lightly, and repeat the procedure of spreading between the toes as much as possible and grasping		
PRS Program 35 min.	PRS	Position	Repeat
	① Plié	Second Position : Grand Plié	8
	② Relevé	Second Position : Relevé → Demi Plié	8
	③ Sauté	First Position : Demi Plié → Sauté	8
	After executing ① ② ③, take 60 seconds rest / Repeat 6 times		
Stretching 10 min.	① Sit with both legs spread out and execute the dorsiflexion on one foot ② Hold the foot in both hands and lift them up toward the body ③ Extend the back of the knee as much as possible ④ Carry out alternately from side to side		

The *plié* (P) training is conducted in the second position of the ballet's basic foot, holding the bar with both hands. The method is to spread both feet wider than required in the second position in ballet, then go down deep through demi plié to grand plié, and then return. The whole procedure is repeated eight times. The weight of the body should be evenly distributed to the triangular point of the both feet, the spine should be vertical, and the pelvis should be carried out with care to remain parallel.

The *relevé-demi point* (R) training is conducted in the second position of the basic ballet feet, holding the bar with both hands. The method is to open narrower than the second position in ballet. Slowly do the relevé, and repeat the knee bending and stretching movement eight times in the demi point state. When performing the plié at demi point, raise the spine and pelvis as much as possible, prevent the angle of demi point's feet from lowering when bending and re-stretching the knees, and ensure that the back of the feet and knees are stretched as much as possible. In addition, when performing the relevé, all five toes should be straightened and the center should not be tilted toward the big toe or the small toe. When moving from relevé to plié, the top of the foot should face toward the toe, and the soles of the feet are stretched as much as possible so that the heel is perpendicular to the floor.

The *temps levé sauté* (S) training is conducted in the first position, holding the bar with both hands. The method is to jump up from demi plié, land again in the first position, and then stretch the knees. The whole process is repeated eight times. To avoid excessive use of the thigh muscles, then spine must be straightened and taking off and landing must be done while feeling the back.

As above explained, the PRS program consists of three actions that are executed while supporting both feet. The reason is that the practice of movements supporting with both feet rather than supporting with just one foot helps to effectively perform balance and central stabilization.

2. Sample recruitment and data collection

In this study, 10 subjects were selected to train the PRS program three times a week for eight weeks in total. They were required to perform one of the ballet's movements, the battement relevé, lent at the time of both before and after participating in the program, and their biomechanical data were measured.

The subjects of this study were 10 ballet majors attending an university in Korea. In order to improve the validity of the results by controlling the confounding factors that could affect the results, the subjects were selected only when they meet the following five conditions: ① college ballet majors with more than 4 years of experience, ② subjects who regularly practice ballet 4 or more hours per day on average, ③ those who does no regular exercise other than ballet, ④ those whose body were unbalanced[2], ⑤ those who have chronic pain of 6 months or more in the back or lower extremity.

Data required for analysis was collected using face-to-face interview and biomechanical measurement equipment. First of all, the interview survey was conducted on participants 4 weeks after the PRS program training. The reason for conducting the interview is to reinforce the results of quantitative biomechnical analysis by collecting qualitative evidence that can prove the improvement effect of the PRS program, and to verify the validity of the biomechanical analysis results through cross-validation. Interview was conducted using a structured questionnaire and informed consents were obtained from interviewees before conducting the interview[3]. Since only 10 subjects were experimented in this study, the problem of small samples may exist, and the core purpose of the interview is to compensate for the potential degradation problem of low statistical power through supplementing and interpreting qualitative evidence from the interview.

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2) In a survey conducted before selecting a group of potential experimental subjects, the following question was asked, "Do you think your body is balanced between the left and right sides when centered on the spine and pelvis?" and those who answered, "It is not balanced" were selected as unbalanced ones.

3) For the objectivity of the study, participants were selected from among students who did not have any formal relationship with the author.

Biomechanical data measurement was performed before and after the PRS program using a 3D image analysis device and a ground reaction device. First, before the program, each subject was required to perform the movement of battement relevé lent, and the three-dimensional image and ground reaction force were measured. The measurement was made in the laboratory where the experimental equipment was placed, and the subjects were required to perform sufficient warm-up exercises for smooth performance. Each subject was required to perform the movement within a set spatial coordinate range, and then image data and ground reaction force data were collected. After 8 weeks of th PRS program training, subjects were asked to perform the battement relevé lent again, and the 3D image and ground reaction force were measured.

Biomechanical key variables that measure body balance or posture stability are the variation range of center of mass (COM) and that of center of pressure (COP). The COM of the human body is located near the lower part of the navel, and the range (unit: m) of the interval within which the COM moves across the left-right or the front-back direction can be used as an indicator to reflect body alignment and posture stability. On the other hand, the center of pressure (COP) refers to the point of action of the pressing force when assuming that the pressure distributed on the surface acts intensively on a point. This is a variable representing the distribution of pressure acting on the surface through the soles of the subject's feet. The range (unit: m) of the interval within which the COP moves in the left-right or the front-back directions when performing the battement relevé lent can be understood as an indicator of the subject's ability to control posture or maintain balance.

IV. Analyzed Effects of the PRS Program

1. Analyzing the effects on COM variation range: Posture balance

As implied in the above explanations, the decreased range of COM variation indicates the improved posture balance. The table below shows the results of analyzing the left-right and front-back movement range of the center of mass (COM) during the battement relevé lent execution after 8 weeks of training the PRS program. The left-right movement range of the COM was found to have a statistically significant improvement effect in the movement of raising the legs from the side to the back when the battement relevé lent are executed. A statistically significant difference was also found in the movement from the front to the side when the right battement relevé lent were performed. There was a statistically significant difference only in the movement of raising the leg to the side when performing the left battement relevé lent.

<Table 2> The analyzed effects on COM variation range by movement direction (unit: m)

		Lift Right Leg (Left Axis)			Lift Left Leg (Right Axis)		
		front	side	back	front	side	back
Left-Right Movement Range (m)	Before	0.007	0.016	0.011	0.011	0.012	0.009
	After	0.007	0.012	0.007	0.006	0.007	0.006
	t-value	-0.07	-2.123*	-2.153*	-4.026***	-3.401***	-1.08
	p-vlue	0.946	0.063	0.06	0.003	0.008	0.308
Front-Back Movement Range (m)	Before	0.01	0.019	0.007	0.008	0.017	0.009
	After	0.007	0.008	0.009	0.014	0.007	0.012
	t-value	-1.139	-1.726	0.429	1.313	-2.438*	0.999
	p-vlue	0.284	0.118	0.678	0.222	0.038	0.344

Note: * p<.1, ** p<.05, *** p<.01

The improvement effect found in the above table is attributable to the fact that the muscles moving the legs become to have origin in the pelvis, which is considered as a result of intensively practicing plié in the second position (Eunji Kim, 2014). Since the PRS program was mainly centered on the plié, it is estimated that a consistent effect was observed in the movement of the hip joint to raise the leg sideways. This interpretation could be confirmed again by the qualitative data collected in the interview survey. In the interview survey conducted in the fourth week of training, the majority of participants responded that développé, meaing raising their legs sideways, became more comfortable. The center of mass variation range had a positive improvement effect on most participants, and one participant who responded as shown in the text below during the 4th week interview actually showed the largest improvement effect when lifting sideways.

> "...I'm wrong depending on my condition, but if I do well, my body gets warmed up well, and I feel like I'm doing pull-up, under my hip, back, and stomach well, and when I develop my right leg to the side, my left support leg got better. Originally, the left support leg was unstable, but it didn't shake and the turn improved..." (Participant D Week 4 Interview)

2. Analyzing the effects on COP variation range: Ability to maintain balance

Like in the COM analysis, decreased movement range of COP reflects the improved ability to maintain balance. The results of analyzing the left-right and front-back movement range of the center of pressure during the battement relevé lent operation after training the PRS program for 8 weeks are presented in the table below.

<Table 3> The analyzed effects on COP variation range by movement direction (unit: m)

		Lift Right Leg (Left Axis)			Lift Left Leg (Right Axis)		
		front	side	back	front	side	back
Left-Right Movement Range (m)	Before	0.017	0.143	0.015	0.021	0.179	0.023
	After	0.017	0.119	0.019	0.021	0.126	0.019
	t-value	-0.121	-2.272*	1.127	0.023	-4.279**	-0.499
	p-vlue	0.906	0.049	0.289	0.982	0.002	0.63
Front-Back Movement Range (m)	Before	0.145	0.021	0.21	0.17	0.016	0.189
	After	0.144	0.014	0.144	0.141	0.012	0.166
	t-value	-0.058	-1.568	-1.499	-1.085	-2.610*	-1.062
	p-vlue	0.955	0.151	0.168	0.306	0.028	0.316

Note: * p<.1, ** p<.05, *** p<.01

The left-right movement COP range was analyzed to have a statistically significant difference in lifting the leg to the side when executing the left battement relevé lent. There was also a statistically significant difference when lifting the leg to the side when executing the right battement relevé lent. On the other hand, it was analyzed that there was a statistically significant difference in the movement of the front-back movement of the COP in raising the leg to the side. These data analysis results are consistent with what was obtained in the 4th week interview survey. Every participants stated that the force to press the ground and the movement of raising their legs to the side became improved. In particular, participant G, who was observed to have a great improvement in lifting his legs to the side when executing the battement relevé lent, stated that after the PRS program, he/she experienced an improvement in balancing the imbalanced body.

> “I used to feel comfortable on the right and uncomfortable on the left, but now I think they’re both similarly balanced... ...and my original bad feet are better... ...and I can feel higher up and more tired...” (Interview in Week 4 of Participant G)

By integrating and reanalyzing the above analysis data, it is possible to analyze the lateral balance control ability, that is, whether one can maintain the left-right balance of physical development and balance control. To this end, this study developed a lateral balance measurement equation as shown in the following and calculated the result.

$$Balance = \frac{Min(COP_r, COP_l)}{Max(COP_r, COP_l)} \times 100\%$$

The above equation represents the result of dividing the small value by the large value among the COP movement variation rage value when executing the left battement relevé lent and the value when executing the right battement relevé lent as a percentage. The meaning of this equation is that if the left and right bodies and functions are balanced without lateral bias, the difference between the two values will be small, so the value of the above equation will be close to 100%, and if both sides are balanced, the maximum value will be 100%. If there is an imbalance between both sides, the value will be less than 100%, and the smaller the value, the more severe the imbalance.

The table below, which calculated and presented the lateral balance in this way, shows that the PRS program has a large in magnitude and statistically significant balance improvement effect on the subjects.

<Table 4> Analyzing the effect of Battement relevé lent COP lateral balance

	COP L-R Motion Range: side			COP F-B Motion Range: back		
	Before	After	Diff.	Before	After	Diff.
Mean	65.8%	80.2%	14.4%*	58.6%	79.5%	20.9%**
S.D.	14.4%	17.9%	19.8%	24.8%	10.3%	24.0%
t-value			2.190			2.611
p-value			0.056			0.028

Note: * p<.1, ** p<.05, *** p<.01

The table shows only the left-right stability when lifting sideways and the front-back stability when lifting backward, where statistically significant improvement effects were observed. It can be seen that the lateral balance was improved by 14.4% points when the leg was raised sideways, and by 20.9% points was improved when the leg was raised backward. These results are also consistent with the results of the interview survey. In the interview survey four weeks after the PRS program, participants presented testimonial consistent with the results of biomechanical analysis by stating the improvement effect on lateral balance as follows.

> "I used to use it with the center tilted to one side, but now I'm using the center toward the center... ...the axis of the columnar bridge is less shaky. I used to just lift my legs, but now I feel like I'm holding it up on the axis... ...I feel like my feet are standing. I used to press my feet down, but now I'm trying to pull them up with my back up..." (Participant E Week 4 Interview)

In addition, participants B and G, who had the biggest improvement in the left-right balance stability when lifting their legs to the back, stated the effect of improving the left-right balance of the PRS program they experienced in the 4th week interview survey as follows.

> "The left pelvis felt weaker and pressed than the right, but after the program, I felt like I found the left tension... ...I think I know how to balance when I hold the balance..." (Interview in Week 4 of Participant B)

"I used to feel comfortable on the right and uncomfortable on the left, but now I think they're both similarly balanced..." (Interview in Week 4 of Participant G)

V. Conclusion

In this study, I established theory and hypothesis that ballet majors can prevent injury by improving body balance and stability through training consisting only of ballet basics, and proved them through biomechanical analysis by applying a corresponding ballet basic skills training program. Although the ultimate purpose of the program was to prevent injuries, but due to the nature of empirical research that requires completion of research within a limited time period, it was practically impossible to directly verify the effects. Therefore, instead of directly measuring the effectiveness of injury prevention, I chose an approach to analyze the effects of programs on these concepts under the hypothesis that 'body balance' and 'body stability' are the main causes of injury.

The program is designed to intensively train three of the most basic movements of ballet: plié, relevé, and sauté, each based on functional and anatomical principles that can act on the mechanisms of posture balance control and injury prevention. The PRS program training was conducted three times a week for a total of eight weeks against 10 ballet majors selected as experimental participants based on certain criteria. Analysis of biomechanical and qualitative data collected from participants after 8 weeks of training showed significant improvement in both center of mass (COM) range and center of pressure (COP) range.

The PRS program, which indirectly confirmed the injury prevention effect through the mediating mechanism of body balance or stability, is designed to secure body balance and stability by ballet itself without any separate instruments or props. The PRS program can be expected to be usefully practical in that it can eliminate the inconvenience of sparing separate time or space, and improve the ballet basics by expanding or extending the conventional ballet classes. Such a program can be an opportunity for dancers and the general public who do not major in ballet to familiarize themselves with the basic skills, while also greatly helping to prevent injuries and correct posture in daily life.

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Abstract

발레 기본기 훈련 프로그램의 부상 예방 효과

- 프로그램 참여자들의 경험에 대한 생체역학적 분석 -

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본 연구는 발레 기본기 동작만으로 이루어진 훈련 프로그램으로도 신체 균형 및 자세 제어 능력을 향상시켜 부상을 예방할 수 있다는 이론 및 가설을 수립하고 이에 부합하는 훈련 프로그램을 개발하여 그 효과를 생체역학적 분석 및 질적 조사를 통해 검증하고자 하는 목적으로 수행되었다. 이 프로그램은 발레의 가장 기본 단위가 되는 세 가지 동작, 즉 굽히고(Plié), 올라가서(Relevé) 중심 잡고, 뛰는(Sauté) 스텝들을 집중적으로 훈련하도록 구성되었다. 프로그램의 효과를 검증하기 위해 실험참여자로 선발된 10명의 발레 전공자들을 대상으로 총 8주의 기간 동안 주당 3회의 빈도로 훈련을 실시하였다. 8 주간의 훈련 이후 실험 참여자들에게서 수집한 생체역학적 데이터 및 질적 데이터를 분석한 결과 신체 균형과 균형제어 능력을 측정하는 신체 중심 변위와 압력 중심 변위 모두 유의미한 개선 효과가 발견되었다. 본 연구에서 신체 균형성이라는 매개 기전에 대한 효과가 확인된 PRS 프로그램은 별도의 기구나 소도구 없이 발레 자체로써 신체의 균형성과 안정성을 확보하도록 고안된 프로그램으로서 발레 기본기 훈련의 확장 또는 연장을 통해 발레 기본기를 다지면서 부상도 예방하는 효과를 거둘 수 있다는 점에서 의의를 갖는다.

Keywords: 부상(Injury), 신체 균형성(Body balance), 균형 제어(Balance control), 발레 기본기 프로그램(Ballet basics program), 생체역학 분석(Biomechanical analysis)