TOURO COLLEGE & UNIVERSITY SYSTEM

The Science Journal of the Lander College of Arts and Sciences

Volume 15
Number 1 *Fall 2021*

24-28

2021

Dance Training and Delayed Maturation

Shira Heavenrich

Dance Training and Delayed Maturation

Shira Heavenrich

Shira Heavenrich graduated in Fall 2021 with a Bachelor of Science degree in Biology. She has been accepted to the Physical Therapy DPT programs at New York Medical College and Touro College.

Abstract

The physiological effects of early childhood dance training are constantly being explored and adjusted. It was observed that children in training experience a higher than normal percentage of delayed maturation, both in puberty and bone development. It was suggested that the environmental conditions in which dancers practice, such as malnutrition and too much time spent indoors, as well as biological factors, contribute to the hormonal and cellular disruptions responsible for late development. Undernourishment, as is common in dancers, was found to have a direct correlation with reproductive hormone levels, including reduction in gonadotropin-releasing hormone secretion as well as lower Luteinizing hormone and Follicle-stimulating hormone levels. Low energy availability due to overexertion also plays a role in pubertal development. Furthermore, Vitamin D deficiency from lack of sunlight seems to influence dancers' bone health and development. This paper aims to present some abnormalities in dancers' growth and development, as well as explore the physiological, hormonal, and metabolic reasoning behind such a phenomenon.

Introduction

The universally practiced form of dance, known as ballet, is learned and taught by many in today's world. The biological consequences that follow those who practice it, however, may be hiding beneath the surface. In the United States today 650,000 to 10,400,000 young girls and boys in the United States study ballet in a professional dance studio. Of these students, 9,000 to 45,000 of them move on to higher education in dance training after that (Bronner, et. al. 1999). Considering the prevalence of dance in American children today, one must examine the effects, short term and long term, that intensive training has on the dancer's biological functioning. One of the major areas impacted by ballet training is the development and maturation into puberty. Perhaps the strenuous physical exertion and specific unnatural positioning of the body that ballet training often requires causes some form of malfunction in the onset of menarche, bone development, and general maturation of the body into adulthood.

Discussion

For females, puberty hits most commonly around the age of 12. This means a young girl will begin to experience many changes involving hormonal activity resulting in the development of secondary female characteristics and the start of menstruation. The two main hormones responsible for regulating the menstrual cycle are the Follicle Stimulating Hormone (FSH) and the Luteinizing Hormone (LH). FSH is released by the pituitary gland which then stimulates the ovaries to release estrogen into the bloodstream and stimulates the formation of the ovarian follicle. LH, also released from the pituitary, then takes over and encourages egg maturation and triggers ovulation, the release of the oocyte from the ovary. Low levels of LH specifically can be the result of nutrition disorders such as bulimia and anorexia. Since the ballet world encourages a thin figure, many students suffer from eating disorders leading to delayed reproductive development.

A major factor that contributes to delayed menarche and sexual development has to do with energy dispersal, specifically low energy availability. The body needs energy in order to start the process of the various developmental cycles. However, when one is overexerting oneself and therefore using more energy than the body has readily available, it uses up energy required for physical maturation. This does not necessarily relate to the amount of calories one burns when doing physical activity, but rather to the amount that the subject is pushing him or herself beyond the body's normal limits. This applies to children in professional training courses, who generally practice for at least 50 hours a week, as well as other sports that require intensive professional level training (Rigby 2012). However, ballet training specifically causes females to experience delayed development. Late maturation is defined as a girl who has not shown signs of secondary sexual characteristics by the age of 14 or has not begun menstruating by the age of 16 (Kapczuk 2017). Researchers revealed that the main hormone related to malfunction in the reproductive system is GnRH (gonadotropin-releasing hormone). When the secretion of GnRH is disrupted, LH cannot be released and therefore the regulation of the reproductive cycle is disturbed. A later study revealed that kisspeptin, a hormone directly related to metabolic functioning and nutrition, was discovered to be a positive regulator of GnRH. Undernourishment and low energy availability, as is common in most professional dancers, reduce kisspeptin production. This in-turn, causes a decrease in GnRH secretion, which slows down the entire chain of hormonal reactions that regulate the reproductive functions. An experiment demonstrated that due to a lack of sufficient energy, a group of female dancers experienced delayed menarche. Although proper sexual functioning returned after a break in their training or once they significantly reduced their training time, amenorrhea, or complete lack of menstruation, returned as soon as they restarted heavy physical activity. This study utilized the concept of energy monitoring in the brain. When there is a lack of metabolic nutrition in the brain, it needs to balance the energy among the areas in the most immediate need of energy, such as the large amount of energy used to fuel the performance of grueling dance exercises (Frisch, et al.) This takes away from energy needed for

healthy menarche development and can therefore lead to delayed onset as well as recurring amenorrhea once the high performance activity is reinstituted (Iwas, et.al 2018).

Besides the obvious effects that reproductive hormones have on adolescent maturation, other parts of the endocrine system can influence changes within the reproductive cycles as well. Stress hormones, mainly cortisol, have been shown to play a crucial role in delaying puberty. A group of carp fish who were exposed to extreme changes in water temperature three times a week and successively exhibited a delay in sexual development. Later, researchers assumed this was due to the cortisol released in the carp under stress-inducing conditions. Another experiment was executed in which one group of carp was injected with high concentrations of cortisol and the other group had their cortisol regulators "switched off". While the second group developed normally, the first group showed signs of delayed development of reproductive organs. This confirmed that high levels of stress, indicated by the increase in cortisol production, directly impact proper onset of puberty (Allsworth et. al. 2007).

A later study in 2002 tested this theory with human beings. The experiment studied 446 women under the age of 45 who were incarcerated. Many of these women in prison had suffered from highly stressful situations in their lives, including sexual abuse, stressful living conditions, or a parent who was incarcerated. Nine percent of this population of women reported amenorrhea, and 33 percent reported irregularity in their menstrual cycle. Most of the subjects had experienced some stressor or trauma as a child. The conclusion drawn from this study was that incarcerated women are more likely to exhibit irregularity in their menses cycle, which may specifically relate to the high levels of stress that the subjects faced (Thompson).

Considering the fact that young ballet dancers, as well as any child dance training professionally, is subject to a great amount of pressure, whether it be from the parents, the competitive nature of the dance world, or self-induced pressure to perform well, one can conclude that they experience high levels of stress. Recent surveys have shown that professional dancers are more likely to have a psychological stress disorder such as PTSD; 22% percent of dancers showed signs of PTSD as opposed to the average population of which 7 percent have PTSD. Stressful conditions cause the body to react in ways that then prevent the proper reproductive functions from occurring (Munoz 2004).

Another point to consider is the effects vitamin D levels have on the body. The sun is the main source of Vitamin D, and considering the fact that dancers spend a great deal indoors, it is reasonable to suggest that they may be lacking in vitamin D. Many young dancers are also undernourished, and therefore have a deficiency in many key nutrients, including Vitamin D. Vitamin D plays a major role in bone strength and development. It is involved in regulating intestinal calcium absorption and calcium resorption in the bone. Therefore, when there is Vitamin D deficiency, calcium absorption from the intestines is significantly decreased, which in turn stimulates osteoclast production, causing the bone to break down. Osteoclasts also release enzymes to break down the bone matrix, allowing the mobilization of calcium from the bone into the body's circulation. Without Vitamin D, the calcium levels in the bone and body, in general, are not sustained, and calcium begins to consistently leave the skeletal system. If this cycle of bone degradation occurs during the years of childhood development, the bone does not have a chance to be nourished and may not form properly (Mathews, et. al. 2006).

The female athlete triad has become the common term used in reference to the top three disorders in female athletes: eating disorders, amenorrhea, and osteoporosis. While the first two are most well-known in women who play all kinds of sports, osteoporosis is most commonly associated with dance-related activity, specifically ballet. Osteoporosis is directly related to one's bone mass density (BMD), since osteoporotic bones are characterized by a loss in bone density and exist as brittle networks with many holes in the bone's structure.

Bone density may be another element of maturation that is possibly delayed by early dance lessons. On the one hand, it seems that high-impact weight-bearing sports, such as football and hockey, are beneficial for bone strength. This type of activity has been shown to increase bone mass, bone density, and bone turnover, and therefore can help prevent osteoporosis later in life. This is because the tension from the muscles and tendons surrounding the bone force the bone to produce more tissue and build up bone mass and in turn increase bone health. These types of activities such as running, weight lifting, jumping rope, and strength training (i.e. push-ups etc.) involve working the body against gravity. However, the positioning and delicate movements required in ballet training seem to not be conducive for bone mass augmentation. In fact, many professionally-training dancers have reported experiencing osteopenia earlier than normal. Osteopenia, or the gradual loss of bone mass, typically begins around age 35, and is a healthy phenomenon when developed at the normal rate (as opposed to osteoporosis, which is more severe). Premature loss of bone mass appeared to be common in dancers. However, this may be due to the fact the professional dancer figure, typically one of a thin woman is prone to brittle and weak bones (Mathews

et. al. 2006). Furthermore, one might argue that although ballet is not generally classified as a weight-bearing sport, certain key leaping movements, such as grande je tes and entrechats, studied in the field of ballet mimic the gravity-defying activities of standard high impact sports. This could likely cause an increase in bone density and balance out any bone loss caused by low BMI or unnatural twisting of the limbs that grind away at the joints. In fact, a recent 3 year long longitudinal study has shown that prepubertal dancers do experience bone mass augmentation in certain areas of the body, most significantly in the femoral neck and lumbar spine regions. The hip flexors and abdominal muscles are the muscles most often used in ballet and likely put pressure on the femoral neck and lateral lumbar spine areas increasing bone tissue and bone mineral content. The subjects, however, demonstrated that the other upper extremities had not built up a significant level of bone mass when compared with the control group, suggesting that the increased BMD in the abdomen and legs were solely because of the greater weight bearing activity in those parts of the body (Turner, et. al. 2012). While this seems to support the claim that dancing can in fact improve bone strength and development, it is unclear from the ramifications of the study if the increased BMD was a direct result of the subjects' dance training. Being that the dancers ranged from ages 11-14, the bone mass augmentation could have been related to their pubertal growth spurts, in which exponential growth in the hip and leg area often occurs, as opposed to their training. Therefore, the reason behind early osteopenia and osteoporosis in dancers has yet to be completely clarified.

One specific dance move commonly referred to as "turn-out", refers to the total outward rotation of the hips required at all times during classical ballet training. Considering this isn't the natural state for one's hips to be in, this repeated movement often causes pain and degeneration in the pelvic-femoral joint. Turn-out movement can cause dysplasia to develop in the ball-and-socket hip joint so that the two bones don't fit together as they should; specifically the acetabulum socket of the pelvis and the femoral head are misaligned. Over time a dancer may begin to feel pain and deterioration. Studies have observed that ballerinas will ironically lose full range of motion, namely internal rotation and adduction, caused by overuse of the external rotator muscles (Storm, et. al 2018). Additionally, a group of 11-14 year old ballerinas were observed and shown to have a significant decrease in femoral torsion. Many of the dancers were observed to have labral tears, in which the labrum cartilage surrounding the hip joint ripped (Hamilton, et. al. 2006) .

While the effects of dance training on maturation and body health generally seem to be negative, some researchers have suggested there to be some positive effects as well. A study was conducted involving a group of dancers who were rehearsing ballet 10 hours a day over a 17 week period leading up to a professional competition. The study observed girls between the ages of 12 and 15 and attempted to monitor the impacts such training might have on the cardiac autonomic system, puberty, biochemical variabilities, as well as body mass changes. The subjects were tested before and after the 17 week period, and were found to have an increase in body mass, total protein production, and testosterone and cortisol levels. To measure the effects on the autonomic system, the subjects' heart rate variability (HRV) was observed pre and post training and overall higher HRVs were observed after completing the training period (Da Silva, et. al. 2015). Scientists compared this to a previous study that displayed significant improvement in HRV in 16 year old male gymnasts, as well as other studies which showed increased HRV in prepubertal swimmers (Tomova, et. al. 2015)). While this could possibly support the idea that intense physical exertion could improve autonomic performance, it doesn't necessarily take into account other factors that may play a role in the 17 week dance training study specifically. The two studies used as support evidence involved either post pubertal (or at the very least, the tail-end of adolescent maturation), and prepubertal subjects. The dance group experiment, however, was aimed to specifically examine the physiological effects on 12-15 year old girls, in the prime of pubertal maturation. The hormonal changes and increased growth rate that happens during these years may contribute to increased HRV and general fluctuations in the autonomic system. Furthermore, this could also explain the results showing increased body mass and height over the training period. One must consider that the subjects could have likely been in the middle of a growth spurt common to that age group, as well as experienced a general increase in body mass. Perhaps dance training augmented these factors, but there is no specific evidence of such reasoning, especially since this experiment included no control group.

Moreover, the study's results also showed that while body mass increased, the BMI for their age group declined as they continued to train. A dancer's body mass index (BMI) also relates to their delayed development. Studies found that as BMI decreases, the first onset of menarche increases. Since it is common for dancers to have a below average BMI, many will experience their first menses at a later age, demonstrating delayed development (Tomova et. al. 2015). A 2014 study observed 4030 boys from ages 7 to 19 and found that their BMI was directly related to

the timing of puberty onset. The overweight group generally experienced early puberty compared to the normal group, and underweight boys demonstrated a delay in every stage of development (Natural Institute of General Medical Sciences).

Pubertal and specifically menstrual disruption is also commonly caused by a disturbance in one's circadian rhythm. Many young dancers train for numerous hours a day, getting up before dawn and leaving after the sun has already set and spending all those hours in between in a fluorescently lit studio with mirrors instead of windows. This means their body may not be getting enough light stimuli during the day to keep their inner clocks balanced. The circadian rhythm is how the body regulates sleep and alertness based on light stimuli from the surrounding environment. It is a network involving communication between certain parts of the DNA, such as the Period and Cryptochrome genes, and various proteins. These specific genes code for proteins that play a major role in building and nourishing the nucleus in nerve cells while one sleeps. This genetic activity is significantly reduced in the daytime while one is awake. The main "clock" which regulates the body's circadian rhythm is the suprachiasmatic nucleus (SCN), referring to a group of 20,000 neurons located in the hypothalamus. This bundle of nerve cells receives light input directly from the eyes stimulating the brain to signal and inform the rest of the body as to what time of day it is (Reilly 2000). When such a regulation system is disturbed, such as spending too much time indoors without windows or having long work hours beyond the body's natural circadian clock, the body can react in many ways. One side effect observed was amenorrea. The circadian rhythm was found to have an inhibitory effect on luteinizing hormone production, causing there to be a shorter luteal phase in the menstrual cycle, and ultimately leading to amenorrhea. Studies have shown that dancers, flight attendants, and anyone who often experiences quick changes in time zones commonly display disturbances in their hormonal and menstrual cycles (Zhu, et. al. 2020). While the job description of a professionally-training dancer may not include an abnormal night/day schedule such as stewardess or world travelers, it is implicit in the method of training to practice all day in a studio with no access to sunlight and admittedly disturbing their circadian rhythms (Turner, et al. 2012).

Some treatments have been explored as to how best to prevent and treat dancers with delayed maturation. The idea of sex-steroid therapy is a common approach to late onset of puberty. These steroids influence the hypothalamus and pituitary gland to secrete growth hormones and initiate secretion of reproductive hormones. This helps individuals with low GnRH, LH, and FSH levels to mature and to be fertile in the future. An assessment involving a group of health providers revealed that 83 percent of the providers agreed that sex-steroid therapy could jump-start puberty in adolescents experiencing a delay in that area. Other providers have suggested that a method known as "watchful waiting" is ideal, in which continued observation of the subject occurs (Zhu, et al. 2020). However, this proposition may not be aggressive enough, considering how time sensitive the onset of puberty is. A doctor might be careful tracking a patient's development and decide not to introduce medication or therapy since the patient is progressing, albeit slowly. At the point in which the rate of growth is understood to not be improving further, it may be too late. There are also preventative courses of action that can be implemented to lessen the negative conditions that allow delayed puberty to occur. Since malnutrition is so common in dancers, having children eat a balanced diet with plenty of high energy foods is key to avoiding eating disorders and low energy availability. One way to counteract the negative effects of too much time spent indoors could be to instigate light therapy. This requires the subject to sit in front of a light box that emits UV rays, helping the body sleep better and experience a more consistent circadian rhythm. Vitamin D supplements can also be taken to support the buildup of bone and retain calcium levels in the skeletal system.

Conclusion

Conclusively, the physiological effects that intensive dance training has on the growing body must be carefully considered. While ultimately it is up to each individual to decide if dance training is worth all the biological long term risks, there are clearly many signs that point to negative impacts in the areas of maturation, bone development, and onset of puberty. However, one must take into account that each individual has pre-existing conditions and physiological circumstances which may influence how significantly dance plays a role. There are still many areas in which more research must be done to clarify the direct correlations between dance and development, and doctors and researchers today still strive to get a deeper understanding of this phenomenon.

References

Allsworth, Jenifer E, et al. "The Influence of Stress on the Menstrual Cycle among Newly Incarcerated Women." Women's Health Issues : Official Publication of the Jacobs Institute of Women's Health, U.S. National Library of Medicine, 2007

Bronner, Shaw, Worthen-Chaudhari, Lise. 1999/01/01. The Demographics of Dance in the United States Vol 3. Journal of Dance Medicine & Science.

Da Silva, C., Goldberg, T., Soares-Caldeira, L., Dos Santos Oliveira, R., De Paula Ramos, S., & Nakamura, F. (2015, October 14). The effects of 17 weeks of ballet training on the Autonomic Modulation, hormonal and General Biochemical profile of Female Adolescents

Frisch, Rose E., PhD., Grace Wyshak PhD., and Larry Vincent M.D. "Delayed Menarche and Amenorrhea in Ballet Dancers." The New England Journal of Medicine, vol. 303, no. 1, 1980, pp. 17-19

Hamilton D, Aronsen P, Loken JH, et al. Dance training intensity at 11–14 years is associated with femoral torsion in classical ballet dancers. Br J Sports Med. 2006

Iwasa, Takeshi, et al. "Effects of Low Energy Availability on Reproductive Functions and Their Underlying Neuroendocrine Mechanisms." Journal of Clinical Medicine, MDPI, 5 July 2018

Kapczuk. "Elite Athletes and Pubertal Delay." Minerva Pediatrica, U.S. National Library of Medicine

Matthews, B. L., Bennell, K. L., McKay, H. A., Khan, K. M., Baxter-Jones, A. D. G., Mirwald, R. L., & Wark, J. D. (pg 1050-1051) 2006, April 14.

Munoz, M., Piedra, C., Barrios, V., Garrido, G., & Argente, J. (2004, October 01). Changes in bone density and bone markers in rhythmic gymnasts and ballet dancers: Implications for puberty and leptin levels. Retrieved May 10, 2021

Natural Institute of General Medical Sciences Circadian rhythms. (n.d.). Retrieved May 16, 2021

Reilly, Thomas (2000) The Menstrual Cycle and Human Performance: An Overview, Biological Rhythm Research

Rigby, Jennifer. "How Hard Is the Life of a Professional Ballet Dancer?" 25 Jan. 2012

Thomson P;Jaque. "Posttraumatic Stress Disorder and Psychopathology in Dancers." Medical Problems of Performing Artists, U.S. National Library of Medicine

Tomova, A., Robeva, R., & Kumanov, P. (2015, July 01). Influence of the body weight on the onset and progression of puberty in boys

Turner, R., O'Sullivan, E., & Edelstein, J. (2012, March). Hip dysplasia and the performing arts: is there a correlation? Current reviews in musculoskeletal medicine

Zhu, J., Feldman, H. A., Eugster, E. A., Fechner, P. Y., Nahata, L., Thornton, P. S., & Yee-Ming, C. (2020). Practice Variation in Management of Girls and /boys =with Delayed Puberty. Endocrine Practice, 26(3), 267-284