Chapter 2
Screening the Young Dancer: Summarizing Thirty Years of Screening

Nili Steinberg, PhD and Itzhak Siev-Ner, MD

Pertinent Definitions

Screening: The process of applying tools that measure functional capacities in individual dancers such as range of motion (ROM), body alignment, and relevant anatomic deviations. The goal is to help prevent injuries by providing guidance for training adaptations and skill acquisition.
Joint range of motion (ROM): Refers to the number of degrees of motion that are present in a joint, as commonly assessed by use of a goniometer.
Turnout: The ability of a dancer to stand and move with the legs externally rotated at the hip so that the toes are directed diagonally away from the midline of the body.
Joint hypermobility: Joint hypermobility is characterized by increased joint flexibility, where the joints move beyond the "normal" limits. The primary cause of hypermobility is attributed to changes in the collagen fiber structure, which is inherent and determined by the fibrous protein genes. This characteristic is often assessed by use of the Beighton scale.
Anatomical alignment: The arrangement of body segments as seen in various postural positions. The ideal or standard alignment involves a minimal amount of stress and strain and is conducive to maximal efficiency of the body.
Incorrect dance technique: Bad habits or patterns of movement, frequently involving lack of sufficient ROM in a specific joint that is compensated for at other joints, causing excessive shear forces that may result in a breakdown of tissue.

N. Steinberg, PhD (✉)
The Wingate College of Physical Education and Sports Sciences,
Wingate College, Wingate Institute, Netanya, Israel
e-mail: knopp@wincol.ac.il

I. Siev-Ner, MD
Department of Orthopedic Rehabilitation, Sheba Medical Center,
109 Rothschild Blvd., Tel-HaShomer, Tel Aviv, Israel
e-mail: zivner@netvision.net.il

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Introduction

As most dance injuries are caused by overuse or misuse, many dance medicine researchers have been occupied with finding a means to prevent these injuries. In general, this research aims to ascertain whether the injury in question was the result of one or more of the following:

- A structural flaw (i.e., are some anatomical characteristics particularly conducive to injury?);
- A specific dance style (ballet, modern, jazz, etc.);
- Faulty technique that exposes the tissues to excessively high loads;
- Intensity (i.e., the tolerance of load is related to the scale of training);
- Age (growth and development);
- Hormonal factors;
- Environment (floor, shoes, studio temperature, etc.); and
- Inadequate nutrition.

It has become obvious that the risks involved are multifactorial, and that in order to draw meaningful and significant conclusions a Sisyphean task is required. These authors set out to develop and implement a screening instrument that could be used with groups of dancers to analyze each individual's potential for overuse injury. The larger, more defined, and uniform the studied groups were, we believed, the more accurate the conclusions drawn would be. The challenge we faced was to know what parameters to examine, record, and compare. At the start we took a decision to collect as many parameters as possible, bearing in mind that some would prove to be insignificant—yet this could not be known until we tested and verified the usefulness of each one. The interpretation of the studies enabled us to understand what is important to ask, collect, and measure. Thus, we now may be able to suggest a target-oriented screening process that is reproducible and can focus on the issues that matter most to the dancers.

Such an effort is worthwhile if the conclusions reached can be implemented and make a difference—e.g., reduce the rate of injuries; prevent unrealistic expectations of young dancers, their parents, and teachers; offer better health and functioning, and longer-lasting careers.

Screening and profiling runs the risk of blocking opportunities to talented students who do not have the "ideal" body type. We should be very careful in establishing what the "best" profile is for a successful dancer. However, if we use the screening information wisely we may be able to anticipate injuries and focus on prevention through proper guidance and cautious teaching.

After a journey that has lasted several decades, screened over 3000 dancers, and involved many skilled scientists, medical personnel, and teachers, we now better understand the risks for injuries, and some of that knowledge is presented in this chapter. The best proof of the value of this information is that the rate of some typical injuries has diminished in the dancers we have screened. Dancers now have a better chance of completing a long career, despite the increasing demands and expectations of such a dynamic and competitive occupation, where the bar keeps moving higher and higher.

Background

The desire to create the "ideal" dancer should not distract us from selecting what are regarded as the best characteristics for a professional dancer. Possessing certain anatomical structures may facilitate achieving the high demands of dance technique, yet much more has to do with talent, artistic qualities, etc. The role of the medical team is not to judge who is going to become a good dancer; our responsibility is to enable each student to do the best they can with their innate qualities, and to promote proper technique and use of their body. As such, the medical team acts as an **advisor** to teachers, dancers, and choreographers; it does not replace them.

Aims of Screening the Young Dancer

The individual student dancer, as well as the teachers and medical team, benefit from the outcomes of screening. The former will be informed of his/her risk factors and how to prevent personal injuries; the latter will better understand the risk factors and mechanisms of injury by deducing conclusions from the accumulated data and its analysis presented in scientific studies.

The art and responsibility of the teachers and medical team is to determine what to assess and what conclusions can be drawn. Thus, the goals are:

1. To detect risk factors at an early stage in order to prevent injuries.
2. To learn the body characteristics of the individual dancer so that they can be used as a baseline for comparison when injuries occur.
3. To collect data for research in order to be able to distinguish between "normal" and any deviation (i.e., to build an ideal profile of the dancer by defining what is "normal").

Collect the Maximum Data

1. Record previous and current impacting factors, such as years of training, age at which female students started pointe work, current hours dancing per day/week, dance style.
2. Measure anatomical and morphological characteristics, such as height and weight, leg length, joint ROM, alignment, and anatomical variations.

3. Obtain information regarding factors that may affect performance (e.g., dance technique), as well as more holistic factors (nutrition, emotional and psychological, etc.).
4. Assess any current injury; record previous medical problems and resulting deficits; identify unrecognized injury.

Timing

Dance students should be screened at the earliest opportunity, preferably prior to, or immediately after, joining a high-level dance class. A full screening should be performed initially, followed by modified screening usually performed at the commencement of each school year.

There may be some specific concerns about the screening protocol during the growth and developmental stages of the young dancer, bearing in mind the different individual (hormonal) maturation rates.

Pre-pubertal Dancers (Age 6–10 Years)

Youngsters may start dance lessons as early as 4 or 5 years old. There are mainly two considerations with the pre-pubertal age group:

1. The manifestation of previously unrecognized congenital deviations;
2. At this age students usually do not sustain high impact injuries; they take one to three classes a week and the classes are short in duration. Yet, during this period they may acquire "imprinting," i.e., faulty movement habits that may follow them for years and eventually become injurious. Hence, the screening staff should make every effort to determine whether the student is being exposed to good instruction.

The medical staff can exert a great deal of influence on the dancer's education, because habits are just being established and brain plasticity is still quite malleable. After the correct methods of dance technique are explained a high degree of compliance can be expected.

Pubertal Dancers (Age 11–14 Years)

Most dancers at this age are involved in a considerable number of practice hours per week (h/week), and the effect of time and highly demanding exercises on their maturation should be addressed. During the pubertal period dancers are undergoing rapid growth and developmental changes, accompanied by risk factors related to the "growth spurt". Bones normally grow faster than ligaments and tendons (which become "shorter" relative to bone length), and dancers who force their soft tissues into larger ROM expose themselves to a higher incidence of injury [1, 2]. Students who sense that their ROM is decreasing may force the joints beyond their limit, creating mini tendon and muscle tears that will scar the soft tissues and further limit the joints' range, thus initiating a vicious cycle. Simple explanations by a teacher or screener may avert these consequences.

Excessive repetitive movements such as working en pointe and demi-pointe may create high load and strain on muscles and ligaments and have been found to increase the prevalence of injuries during the pubertal period [3, 4]. Most dance educators and healthcare practitioners would agree that dancers need a minimum of 3–4 years of ballet training and the attainment of the chronological age of 12 years before they can acquire the technical skill and motor control necessary to begin en pointe work [5, 6].

Adolescent Dancers (Age 15–18 Years)

This group includes students who usually have had some years of practice, yet there may also be some beginners. At this age the intensity as well as the total number of training h/week increases significantly, sometimes reaching a "semi-professional" level and load. These dancers are at the highest exposure to risk. Their motivation and ambition might exacerbate the risk, as this is also the time they will elect or be selected to devote themselves to becoming professional dancers.

Insights from the Screening

Age

Young (age 6–18 years) dancers are a unique group. As previously stated, they are in the phase of growth and development. Their dance intensity and hours of practice can place a great physical load on their growing musculoskeletal system. Certain dance techniques (such as dancing en pointe) may exceed the young dancer's ability to cope with the high demands during this period.

The results from screening 1336 young dancers demonstrated an increased prevalence of injuries in the age group of 8–16; whereas at 8 years old one out of 10 girls experienced an injury, by the age of 16 every third girl had suffered an injury [7]. On the other hand, another study of 806 young dancers attending Centres for Advanced Training (UK) demonstrated no difference in the rate of injuries with increasing age (11–18 years) [8]. Most dancers trained from 6 to 11 years before their first injury occurred [7]. A high rate of dancers with recurrent injury (27.7%) is already noted in dancers of a very young age (9 years), a rate that rises to 46% at the age of 16 years [7]. The average time elapsed between the first and second injury is age-dependent; the older the dancer, the smaller the time gap between the first and second injury [7].

Dance History

Obtaining the students' dance history reveals information regarding the number of years they were exposed to dancing and its possible accumulative impact on their bodies. Specific screening questions should refer to the age that they started the following:

- Dance classes,
- Ballet dancing,
- Modern dancing,
- Other types of dancing,
- Dancing more than 10 h per week, and
- Dancing en pointe.

Impact of the Current Training Program

Specific questions concerning the current impact of dance training should include the following:

- Total hours of practice per week in each technique,
- Number of days per week that the dancer practices more than 4 h/day, and
- Total h/week of en pointe work.

Screening of 1336 young dancers showed no statistically significant association between total h/week of dance training and injuries, although the injured girls tended to dance more h/week than the non-injured dancers. A significant association between dance practice in a specific position (en pointe) and injury was observed ($p < 0.001$): 43% of the dancers who trained en pointe more than 60 min per week had an injury compared with just 29% of the dancers who practiced this position for less than 60 min per week [9]. Among the 806 UK dancers mentioned earlier the young injured dancers practiced more h/week than the non-injured dancers of the same age cohort. The percentage of injured dancers who practiced more than 2 h/week in modern dance style was higher than the percentage of injured dancers who practiced between 1 and 2 h/week of modern dance. No differences were found between dancers who practiced >3 h/week of ballet and dancers who practiced <3 h/week of ballet [8].

Age at Onset of Menarche

The screening should address:

- Age at onset of menarche,
- Frequency of menarche (regular/irregular), and
- Dysmenorrhea (yes/no).

Extensive involvement in sport may delay physical development and menstrual function [10], unless the activity is reduced [11]. Young female dancers showed delayed age at menarche and higher frequency of delayed menarche compared with age-matched controls [12–14].

Dancers who began training before menarche have been shown to experience a later menarche and had an increased incidence of menstrual dysfunction when compared to girls who began training after menarche [12–14]. Dancers with delayed menarche have manifested lower body weight, lower bone mass, and higher frequency of stress fractures at the transitional stages of puberty than dancers with normal age onset of menarche [15, 16]. As a certain percentage of body fat (>17%) is necessary for regular ovulatory cycles, it is understandable that nutritional shortcomings, low body fat, and a high ratio of lean mass to body weight in young dancers will delay the adolescent growth spurt, retard the onset of menarche, and cause menstrual disturbance [2, 17]. Comparing age at menarche of injured and non-injured dancers showed no significant difference. Injured dancers had more occasions when their menarche stopped for ≥ 3 months compared to non-injured dancers [8]. Screening a large group of young non-professional dancers demonstrated no association between the age of onset of menarche and injuries, manifestation of scoliosis, joint hypermobility, or hallux valgus [4, 18–20].

Anthropometric Measures

Data concerning weight, height, and BMI are essential for understanding the anthropometric characteristics of the young dancer. Young dancers are significantly leaner and have lower BMI compared to age-matched non-dancer controls [21–23]. The low body weight found in young ballet dancers is most likely associated with a light skeletal frame and below average amount of muscle tissue [23].

Other anthropometric data, such as leg length (Fig. 2.1) and foot length discrepancies, are important mainly for identifying any deviations from the normal posture. Segmental discrepancies should be noted as they might be predisposing factors for posture mal-alignments such as scoliosis, some common compensatory mechanisms during certain dance movements, and overuse syndromes commonly found among dancers [24, 25].

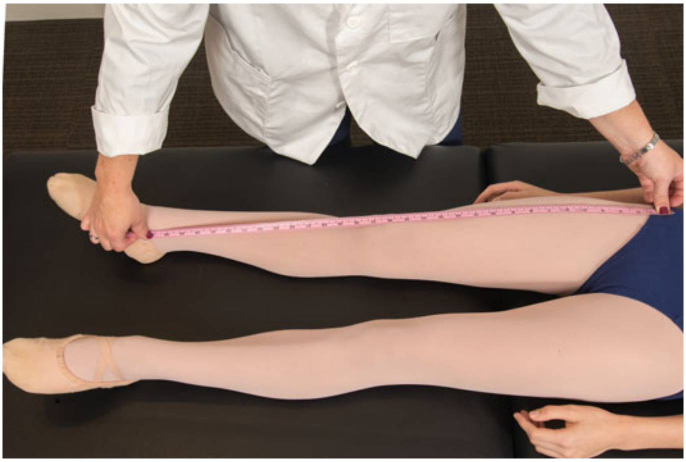

Fig. 2.1 Leg length measurement. Photograph courtesy of James Koepfler

Joint Hypermobility Syndrome

Joint hypermobility is a condition in which most of the synovial joints move beyond the "normal" limits. It is recognized as a feature of heritable disorders of the connective tissue (changes in the collagen fiber structure regulated by the fibrous protein genes) and is generally identified by use of the Beighton scale [26]. Among dancers hypermobility refers to weak joint stability. It is the result of long and loose ligaments and certain structural deviations such as shallow joint surfaces, making dancers with hypermobility more vulnerable to musculoskeletal injury and to prolonged periods of post-injury recovery [27–30].

Hypermobility characteristics are considered by dancers to be of great aesthetic benefit, with general agreement that they confer advantages in career advancement [31, 32]. From a medical point of view, hypermobility is a genetic phenomenon [33, 34], yet some authorities claim that it is related to years of incorrect technical execution of dance exercises, which is capable of exacerbating the condition [35].

Among young dancers (aged 8–16 years) joint hypermobility was found to be very common and showed an increased prevalence with increasing age [20]. This is likely due in part to some self-selection of body type, with dancers who could not match what is perceived to be the "perfect" dance movements performed by their hypermobile counterparts dropping out [2, 36, 37]. Teachers frequently promote this process by favoring those dancers who exemplify the aesthetically "correct body shape" to become professionals [2, 36, 37].

Hypermobility should be addressed in young dancers, as pubertal hypermobile female dancers are at high risk for suffering from chronic musculoskeletal pain and arthralgia [2, 36, 37]. It has been frequently observed that young female dancers with hypermobility and resulting pain have lower motivation, higher prevalence of dropout from their ballet career, and greater risk for injuries compared to their peers [32, 35, 36, 38].

Knee Laxity

Screening examination should include:

- Laxity around the knee joint: medial/lateral laxity of the knee (Fig. 2.2);
- Lachman test and drawer test;
- Medial/lateral mobility of patella in extended knee; and
- Medial/lateral mobility of patella in 30° of knee flexion.

In one study adolescent dancers (12–14 years old) with patellofemoral pain syndrome were found to have greater prevalence of patellar laxity in the extended knee and in 30° flexion of the knee compared to non-injured dancers [39]. It was suggested that excessive lateral tracking of the patella increased the forces and stresses between the patellar articular surface and the femur throughout knee ROM [39]. Although another study showed that patellar mobility was not associated with the development of patellofemoral pain syndrome [39], knee instability should be screened as it might predispose the dancer to overuse injuries [40].

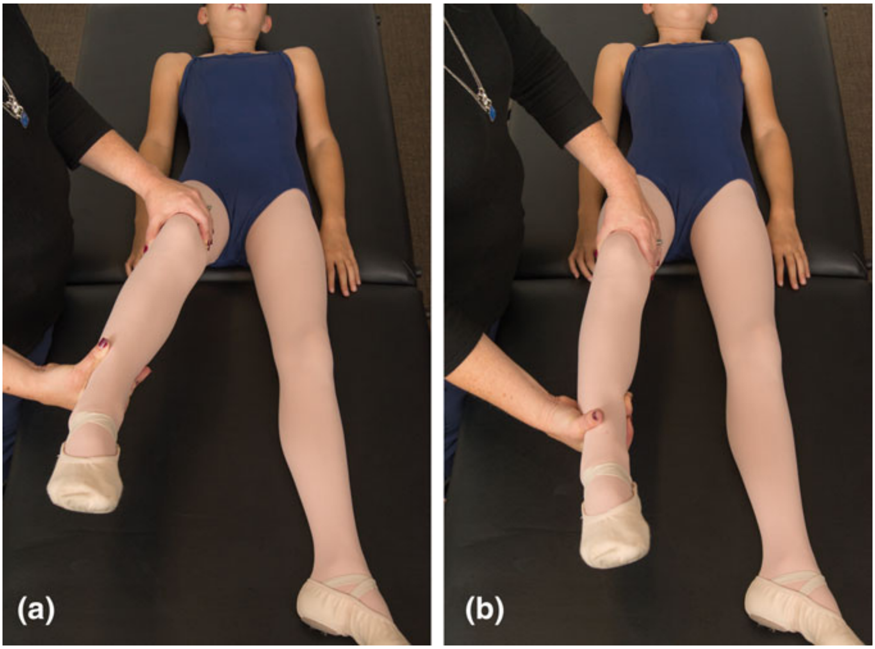

Fig. 2.2 Knee lateral (**a**) and medial (**b**) laxity assessments. Photographs courtesy of James Koepfler

Passive Joint ROM

Dancers should be screened for the most important joints' ROM (Fig. 2.3):

- Hip (flexion, extension, abduction, external rotation, internal rotation);
- Knee (flexion, extension);
- Ankle (dorsiflexion, plantar flexion);
- Foot (en pointe); and
- Combined joints' ROM (lower back and hamstring).

The ROM measurement procedure was described previously by a number of experts in dance medicine who determined the norms and movements essential in dance-related screening [41, 42] (Table 2.1).

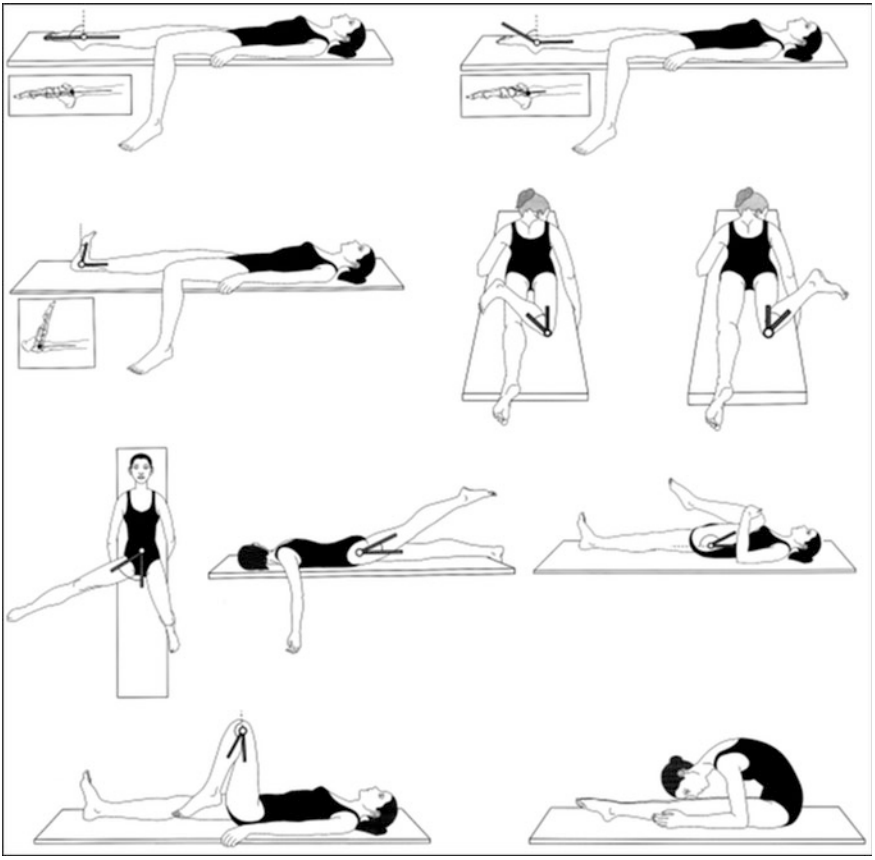

Fig. 2.3 From *left to right*: *Upper row*, combined passive ankle and foot plantar flexion (pointe); passive plantar flexion of the ankle joint. *Second row*, passive dorsiflexion of the ankle joint; passive external rotation of the hip joint; passive internal rotation of the hip joint. *Third row*, passive abduction of the hip joint; active extension of the hip joint; passive flexion of the hip joint. *Bottom row*, passive flexion of the knee joint; lower back and hamstring flexibility. Reprinted with permission from Steinberg et al. [43]

Table 2.1 Passive joint ROM: physician observations and classifications into 3 groups: hypo ROM (> −1 S.D. of mean), average ROM (±1 S.D. of mean), and hyper ROM (> +1 S.D. of mean), based on ROM distribution for each joint obtained from 1314 dancers aged 8–16 years [43]

Joint	Passive movement	Physician observations	Classifications
Foot and ankle	Dorsiflexion	The angle between the long axis of the medial border of the tibia and the long axis of the medial aspect of the foot	Limited ROM $\leq$ 5° Average ROM 6–15° Hyper ROM $\geq$ 16°
	Plantar flexion	The angle between the long axis of the medial border of the tibia and the manually palpated navicular	Limited ROM $\leq$ 45° Average ROM 46–64° Hyper ROM $\geq$ 65°
	En pointe	The angle between the long axis of the medial border of the tibia and the manually palpated distal head of the first metatarsal	Limited ROM $\leq$ 75° Average ROM 76–90° Hyper ROM $\geq$ 91°
Knee	Extension	In the extended knee, the angle between the long axis of the thigh and the long axis of the tibia	Average ROM 0° Hyper ROM $\geq$ 5°
	Flexion	In the flexed knee, the angle between the long axis of the thigh and the long axis of the tibia	Limited ROM $\leq$ 140° Average ROM 141–150° Hyper ROM $\geq$ 151°
Hip	Active extension	In the active extended hip, the angle between the midaxillary line (the axis on the greater trochanter) and the long axis of the thigh between the greater trochanter and the lateral epicondyle of the femur	Limited ROM $\leq$ 20° Average ROM 21–39° Hyper ROM $\geq$ 40°
	Flexion	In flexed hip, the angle between the midaxillary line (the axis on the greater trochanter) and the long axis of the thigh between the greater trochanter and the lateral epicondyle of the femur	Limited ROM $\leq$ 135° Average ROM 136–150° Hyper ROM $\geq$ 151°
	Abduction	Hip abducted in frontal plane in neutral rotation (of the hip) with the foot perpendicular to the floor. Range was measured between a line from the umbilicus and the symphysis pubis and the long axis of the abducted thigh (between the umbilicus and the patella)	Limited ROM $\leq$ 45° Average ROM 46–59° Hyper ROM $\geq$ 60°

(continued)

Table 2.1 (continued)

Joint	Passive movement	Physician observations	Classifications
	External rotation	In the flexed knee and externally rotated hip, the angle between the vertical axis and the anterior border of the tibia	Limited ROM $\leq$ 50° Average ROM 51–60° Hyper ROM $\geq$ 61°
	Internal rotation	In the flexed knee and internally rotated hip, the angle between the vertical axis and the anterior border of the tibia	Limited ROM $\leq$ 45° Average ROM 46–65° Hyper ROM $\geq$ 66°
Lower back and hamstrings	Flexion	In extended knees and planter-flexed ankles, the dancer leaned forward with the forehead toward her knees	Limited ROM $\leq$ 1 cm distance between forehead and knees. Hyper ROM $\geq$ forehead touching the knees

The term joint ROM is defined by the "musculotendinous unit length" and the "musculotendinous unit flexibility," and thus refers to the ROM available in a single joint [44, 45]. Several factors affect joint ROM in a particular joint, including the shape of the articulating surface, the shape of the articular capsule, ligamentous structures, the structure of the bony surfaces, muscle fat content, and muscle tension. All of these are genetically determined [46, 47]. There are clinical guidelines and norms for evaluating each specific joint (such as the hip, knee, and ankle joints) and each specific passive movement (such as flexion, extension, and rotation), which are normally measured with a goniometer [48, 49]. Increased joint ROM can create the illusion of perfect movements or positions, and has therefore been identified as a prerequisite for successful dancers [2, 50].

The classic question "Which came first, the chicken or the egg?" is relevant with regard to ROM. There are two schools of thought; for decades there was an argument in the literature as to whether joint ROM is solely dictated by genetics or if long periods and intensity of dance training may increase joint ROM. We should also question whether deviant joint ROM (insufficient or excessive) increases the risk of injury. With regard to the first question, in most studies dancers manifested greater joint ROM compared to non-dancers [43, 51]. A study of 1314 young female dancers found that ROM did not improve or diminish with age, but rather was preserved [43]. The ability of dancers to retain joint flexibility with age is probably due to regular training, as ROM in non-dancers tends to decrease with age [43]. Conversely, Hamilton et al. [2] explain that the desired dancer en pointe ROM (90°–100°) results from constant stretching and skeletal modeling while the bones are growing. It was suggested that improvement in hip external rotation ROM was attributable to structural changes in the femur (anteversion/retroversion of the femoral neck) as a result of the growth process controlled by hormonal changes during the spurt period, along with capsular stretching [2, 52].

Concerning the relationship between a deviated joint ROM and the risk of injury, insufficient or excessive joint ROM have been suggested as important intrinsic characteristics that may alter the biomechanics of dance movements and therefore be associated with dance injuries [2, 9, 50, 53, 54]. For example, insufficient ankle plantar flexion was found to be more common among injured dancers [53]; hyper (increased) joint ROM in the lower extremity was found to be associated with increased rate of ankle/foot paratendonitis [4]; and dancers who practice en pointe in “turnout” position with insufficient joint stability predispose themselves to injury [55].

Dancers with increased (hyper) joint ROM may exhibit excessive motion, inappropriate direction of forces, and failure of the muscles acting around the joints to keep the correct kinematic movement pattern, which can result in injuries to the affected tissues [56, 57]. Conversely, dancers who lack the required joint ROM for ideal positions tend to develop compensatory strategies [56, 58], which, in turn, may lead to an injury [28, 57]. Nevertheless, a study by Steinberg et al. [9] reported opposing results: dancers with decreased hip and ankle/foot joint ROM were found to be less prone to develop patellofemoral pain syndrome [54], and Wiesler et al. [59] reported no predictive relationship between ankle ROM measurements and injury in 148 elite adolescent pre-professional dancers.

The correct conclusion probably lies in the sample size and the cohort studied. Most compensatory movements probably contribute to pathologies. However, the large group studied [52] who underwent screening demonstrated that lack of “ideal” ROM does not necessarily cause injuries if ROM is not forced by compensations.

Unlike hypermobile (unstable) joints, which demand greater effort from the muscles around the joint to stabilize and control movement in order to prevent injuries, the mirror image of limited ROM needs “only” to avoid forcing a non-existing range, and hence prevent negative compensation and injuries.

Anatomical Alignment

Screening young dancers for joint malalignment and structural deviations may reduce the risk for related injuries (Table 2.2):

- Knee valgum/varum
- Forefoot adduction
- Hind-foot varum/valgum
- Longitudinal arch cavus/planus (splay foot)
- Hallux valgus
- Lordosis
- Scoliosis

Table 2.2 Anatomical anomalies

Joint	Anomalies	Physician observations (in an anatomical position)	Definition of a positive test[a]
Foot and ankle	Longitudinal arch planus (LAP)/ Longitudinal arch cavus (LAC)	Viewing the medial aspect of the foot, an increased height of the medial longitudinal arch indicates LAC, and reduced height of the medial longitudinal arch, with its margins touching the ground, indicates LAP.	Planus: Forefoot inversion, pes planus Cavus: Forefoot eversion
	Calcaneal valgus/varum	Viewed from behind, for varum the calcaneus is inverted when the subtalar joint is in a neutral position; for valgus the calcaneus is everted when the subtalar joint is in a neutral position	Varum: >5° inversion from calcaneal midline Valgus: <5° eversion from calcaneal midline
	Hallux valgus	Viewing the dorsal aspect of the foot, hallux valgus is present when the first metatarsal is lateromedially oriented and the proximal phalanx mediolaterally oriented. A callus is also present at the medial aspect of the head of the first metatarsal.	>15° at MTP
Knee	Valgus/varum	Viewing the anterior aspect of the lower extremities, with the knees fully extended: valgus is considered if the tibia has a valgus angulation in comparison to the femur (the dancer's knees touch and the ankles do not); varum is considered present if the tibia has a varum angulation in comparison to the femur (the dancer's ankles touch and her knees do not). The knees are in correct alignment when the hips are neutral in rotation and the patellae are facing directly forward.	Knee valgus: Q angle >22° in females, >18° in males with knees extended. Knee varum: Space between the right and left knee with feet together in stance
	Genu-recurvatum	Viewing the lateral aspect of the lower extremities with the knees fully extended, genu-recurvatum is considered present if the femur is fully extended and the legs have a posterior angulation	>10° Hyperextension

(continued)

Table 2.2 (continued)

Joint	Anomalies	Physician observations (in an anatomical position)	Definition of a positive test[a]
Back	Scoliosis	(A) Magee's "skyline" view: any deviation from the normal posture: the head is straight on the shoulders; the posture of the jaw is normal; the tip of the nose is in line with the sternum; the trapezius neck line is equal on both sides; the shoulders are level; the clavicles are level; there is no protrusion, depression, or lateralization of the sternum, ribs, or costocartilage; the waist angles are equal, and the arms are equidistant from the waist; the carrying angle at each angle is equal, the palms of both hands face the body in the relaxed standing position; the high points of the iliac crest are the same on both sides; the ASIS are level; the pubic bone is level; the knees are straight; the heads of fibula are level; the ankles are level; the arches of the feet are equal on both sides; the feet angle out equally; there is no bowing of bones. (B) The Adams forward-bend test: when the dancer flexes her spine forward from a standing position scoliosis is considered when any hump on one side and a hollow on the other is detected. A positive test means that a rib hump deformity is noted in the thoracic region, or that an angle of trunk rotation is evident in the thoracolumbar or lumbar region.	Adams forward-bend test: thoracic: no posterior rib hump at 30° Lumbar: no increased muscle bulk at 90° of forward flexion

[a]According to Karim et al. [60]

Limited data are available regarding an association between static postural alignment and injuries. One study found a correlation between scoliosis and injuries among dancers aged 8–16 years [9]. Most other studies measured the *dynamic* alignment of dancers during active dance movements, suggesting that poor *dynamic* lower extremity alignment increased the risk of injury among young dancers [53, 61].

Hallux Valgus

Hallux valgus is a common deformity in the female population as a whole, and among athletes and dancers in particular [19, 62]. Prevalence of hallux valgus among young dancers (age 8–16 years) is very high (40%), and increases from pre-pubertal age (8–10 years: 32.7%) to pubertal age (11–13 years: 45.6%) [19]. Hallux valgus in dancers may result from various factors, such as the genetic component; the increased lever arm of the long hallux acting on the MP joint through an extreme ROM; increased stress on the MP joint during demi-pointe work; forced turnout (leading to rolling in) in demi-plié that also leads to excessive internal rotation of the tibia; and excessive movements such as en pointe work [62–64]. It has been suggested that hyper-pronation ("rolling in") can result in abnormal pressure distribution throughout the foot, which can place the dancer at risk for developing hallux valgus [65]. To summarize, genetic predisposition together with faulty technique might be the inappropriate combination that explains the high rate of hallux valgus in dancers. The greater the deformity the higher the chance that it will adversely influence the dancing by causing pain, bursitis, and limited ROM—all of which negatively impact the performance of the dancer. As surgical correction of hallux valgus deformities in dancers may decrease the power or ROM at the first MP joint muscles and ligaments [66], the most common recommendation for dancers is to adhere to conservative measures and avoid corrective surgery, preserving the range of dorsiflexion at the joint, which is a necessity for dancers [62].

Hallux valgus was found to be associated with other spinal and lower extremity joint mal-alignments such as scoliosis and knee varum [19], but no correlation between h/week of ballet practice and hallux valgus or h/week of en pointe dancing and hallux valgus have been reported among dancers [19, 63]. Given the prevalence and severity of hallux valgus with increasing age, it is suggested that hallux valgus is mostly related to hereditary anatomical factors and to incorrect technical execution [63].

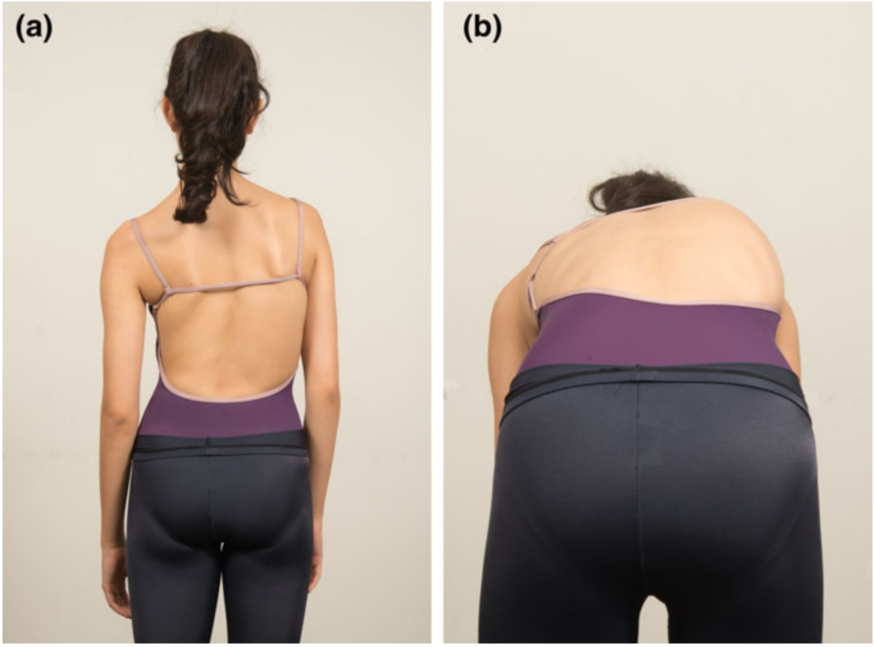

Fig. 2.4 Magee's "skyline" view (**a**) and the Adams forward-bend test (**b**). Photographs courtesy of James Koepfler

Scoliosis

There is a high incidence of scoliosis in athletic girls and dancers compared to their age-matched controls [67, 68]. In a screening examination performed by an orthopedic surgeon utilizing the Magee's "skyline" view (Fig. 2.4a) and the Adams forward-bend test (Fig. 2.4b), the prevalence of scoliosis was found to be 24–30% among recreational dancers, 30% among adolescent ballet dancers, and 24% in young professional dancers [15, 18, 69]. Scoliosis had already been noted in 22.6% of dancers at the age of 9, a prevalence that increased slightly to 26.3% at 16 years old [18].

The relationship between factors such as growth processes, intensive exercise, and scoliosis is not clear. A number of researchers have claimed that dance is a highly repetitive activity that imposes high stress on the immature spine, and that ballet training may delay menarche and predispose dancers to develop scoliosis and stress fractures [15, 68, 70]. Furthermore, it is suggested that the stresses exerted on the scoliotic spine over many years may be associated with an increased incidence of specific injuries to the scoliotic dancers [70], with a high incidence of injuries such as low back pain [9, 15, 18, 53]. Other researchers have claimed that intensive dance training may improve scoliosis [71], as dance classes involve symmetric and balanced exercises. Hence, no differences were found between scoliotic and non-scoliotic dancers in training impact parameters (mean age at which students started dance classes, mean h/week of dance practice, and mean number of years of practice) [18].

Identifying other anatomical anomalies during screening of a scoliotic dancer is important, as mal-alignments such as knee varum, genu-recurvatum, long-plantar planus, splay foot, and hallux valgus were found more frequently among scoliotic dancers than non-scoliotic dancers [18].

Physical Fitness (Muscle Strength Assessments)

Dance physical fitness depends on individuals' ability to work under aerobic and anaerobic conditions, and on their capacity to develop high levels of fitness parameters, such as muscle strength. Although no fitness measurement can predict success in dance, detection of muscle weakness is a powerful indicator of future injury [46].

Previous data have suggested that dance injuries are related mainly to the simultaneous presence of strong and weak muscles in the same limb [46]. Most injuries to the knee and lower leg occur due to diminished hip and knee muscle strength, which leads to faulty lower extremity alignment [52, 72]. Decreased strength may lead to faulty biomechanics of the lower extremity, particularly when the dancer tries to maintain neutral alignment during single leg landings [73]. Monitoring the strength of hip abductors, knee extensors, and ankle evertors is important, as during movement those muscles should control alignment of the lower extremities so that the patella remains in line with the second toe and the foot is placed in the correct position [74]. Thus, any muscle deficits or imbalance might predispose dancers to higher risk of injury [2]. Studies of young dancers showed that female dancers aged 8–11 years had weaker hip muscles than age-matched controls, except for hip abductor strength, which was similar. Yet, the dancers had the ability to improve their hip strength (in specific dance-related muscles) in a 12-month strengthening program, suggesting that hip strength can be trained at this young age [52, 58].

Dance Technique (Sickling in, Rolling in, and Hyperlordosis)

"Sickling in" refers to varus alignment of the foot, with increased stress on the lateral structures of the ankle [64, 66]. "Rolling in" refers to valgus heel with forefoot pronation [64, 75, 76] (Fig. 2.5). Hyperlordosis refers to anterior pelvic tilt or lumbar lordosis, which generates undue stress on the posterior elements of the spine [64] (Fig. 2.6; Table 2.3).

Screening young dancers for improper posture and technique is important, as using compensatory strategies is known to be a common phenomenon among ballet dancers and has been strongly linked to overuse injuries [9, 76–78]. Screening programs should address postural compensations in specific positions and should increase the dancers' self-awareness of their physical limitations, as well as the teachers' awareness.

Fig. 2.5 "Rolling in" during turnout. Photograph courtesy of James Koepfler

Fig. 2.6 Hyperlordosis during turnout. Photograph courtesy of James Koepfler

Considering the fact that limited joint ROM may trigger technique compensations that can lead to injury [2], education of dancers and teachers should emphasize correct dance positions and avoidance of compensation and stress, in accordance with the anatomic structure of each individual and based on his/her natural ROM [43, 76]. For example, dancers who try to achieve perfect “turnout” often compensate for insufficient hip motion by rotating at the knees, everting the heels, pronating the feet, and increasing the lordosis in their lumbar spine, which may be the origin of some of the spinal and lower extremity injuries seen in dancers [4, 77–80]. In addition, dancers with limited ankle plantar flexion compensate for this by using poor techniques that shift much of the load to their adjacent joints, including the knees [81]. Improving dance technique (e.g., correcting for neutral lower extremity alignment) may reduce the need for compensatory strategies, and therefore reduce the risk of injury [73].

Table 2.3 Dance technique

Technique	Physician observations	Comments
Sickling out/sickling in	The dancer was asked to perform a relevé: Correct technique is when the dancer rises up on the ball of the foot and the weight is in a straight line with the forefoot. Incorrect technique is when the dancer places weight onto the lateral (sickling out) or medial (sickling in) borders of her feet.	(1) The dancer is asked to demonstrate each technique 1–3 times at her usual speed, and 1–3 times as slowly as possible. (2) Technique movements were categorized as either correct or incorrect.
Hyperlordosis	The dancer was asked to perform a turnout position: correct technique is when the dancer externally rotates her hips, legs, and feet, without anterior pelvic tilt; incorrect technique is when the dancer tries to compensate for poor "turnout" by tilting the pelvis forward (hyperlordosis).	
Rolling in	The dancer was asked to perform a plié in first position: correct technique is when the patella is above the second toe; incorrect technique is when the patella is above or medial to the first toe (rolling in).	

Extrinsic Relevant Factors

Motivation and Adherence to Dance

The benefits of dancing include improvement in psychological well-being, increased self-esteem, and anxiety reduction. Thorough understanding on the part of teachers and screeners of the motivational stimulus of young dancers through readily available and reliable tools (such as the "Dance Motivation Inventory-DMI") is recommended [82, 83]. One should consider the high level of competition between students, the role model of the teacher, the body image confronting dancers in the mirror during classes, the emotional stress of adolescence, and stage fright.

Eating Habits

When a dancer is found to be at risk for disordered eating on the basis of screening measures (weight significantly lower than expected for age and height) a detailed assessment of eating habits and exploration of risk factors for disordered eating and poor self-image should be undertaken [84]. Validated screening tools exist for the detection of disordered eating behavior in athletes, including the Athletic Milieu Direct Questionnaire (AMDQ) [85], the Female Athlete Screening Tool (FAST) [86], the American Physiological Screening Test for eating disorders among Female College Athletes (PST) [87], the Low Energy Availability in Females Questionnaire (LEAF-Q) [88], and others designed to identify female athletes at risk for the "Triad" (a syndrome comprised of disordered eating, menstrual irregularity, and impaired bone health).

Musculoskeletal Injuries

The aim of musculoskeletal screening is to assess recovery from any previous injury and the presence of risk factors for future injury. The dancer should be asked about any previous or current injury/pain [7]. When a positive answer is obtained the dancer should be asked to describe the mechanism of injury—that is, the movements or exercises that precipitated the injury—and the extent to which the injury affects dancing and daily life activities. Dancers who report pain or dysfunction should be examined by a physician specializing in dance medicine. A clinical examination is required to reveal reproduction of pain or signs of injury (such as swelling, instability, reduced ROM.) [7, 9]. When additional confirmation is required, radiographs, ultrasound, computed tomography, or magnetic resonance imaging should be performed.

Injury Prevention

The medical screening process is an opportunity to identify potential risk factors and implement measures designed to reduce those risks. It is also an opportunity to ensure that medical equipment and assistive devices (such as scoliosis braces and proprioceptive insoles) are being used appropriately by injured dancers.

Summary

Screening provides an opportunity for the young dancer to be examined by experts in dance medicine—often for the first time in his/her life. The screening process may provide the dancers, their parents, their dance teachers, and the clinical team with useful information relevant to the future management of the dancer.

Most authors describe the majority of injuries in dancers as occurring in the lower leg and lumbar regions [5, 6, 89], with a different distribution of injuries between the youngest dancers (age 6–10 years) and adolescent dancers (age 14–18 years) [5, 6], and a different distribution between the two genders [89]. Injury incidence per 1000 h of practice indicated that the average for young dancers ranged from 0.8 to 8.4 [5, 6, 43, 90].

The data provided by methodological screenings and processing of accumulated knowledge from the literature enable teachers and medical staff to formulate solid conclusions that improve their care of the student dancer.

The task has not been completed; further intervention and longitudinal research will assist in determining associations between screening results and outcomes, with a better understanding of the relationship between various characteristics of the young dancer and risk factors for dance injuries.

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