With the continued increase of video gaming around the world, we present a review of the literature on vascular injuries associated with gaming to explore any common mechanisms of vascular injuries sustained and make recommendations to prevent them. A 2017 systematic review of all reported vascular injuries associated with video gaming was performed using Medline and PubMed searches including the following keywords: “Thrombosis” or “Artery” or “Vascular” or “ethrombosis” and “Video game” or “Wii” or “Nintendo” or “Wiiitis” or “Computer game.” A total of 11 case reports reporting 12 vascular injuries associated with gaming were identified. Nine vascular injuries from gaming were associated with venous thromboembolism (VTE). Nearly 67% of cases resulted in major pulmonary emboli, one fatal. In the majority of VTE cases, the only risk factor known was prolonged immobility. All cases had negative thrombophilia screens or no history of thrombophilia. Two injuries occurred from intense physical activity on Nintendo Wii causing internal carotid artery dissection and permanent disability. One case was of an intraventricular hemorrhage from an arteriovenous malformation rupture occurring during gaming causing neurological deficits. Most vascular injuries from gaming were related to VTE. Immobility appears to be the solitary risk factor reported in most of the cases, an unusual finding with regard to the multifactorial nature of VTE pathogenesis. We recommend gamers not remain immobile for more than one continuous hour, taking breaks to mobilize or perform lower limb exercises.

Keywords: E-thrombosis, vascular, venous thromboembolism, video games, Wii

In 2016, the dramatic increase in worldwide participation of smartphone based game Pokémon Go (Niantic laboratories) was followed by several highly publicized injuries to gamers, largely related to player distraction while trying to catch game characters in the community.[1] However, before this game or even the smartphone, the literature has catalogued a multitude of various adverse medical issues associated with video games. With the on-going increase of video game or smartphone game participation, there is expected to be an associated rise in gaming injuries with a shift in mechanisms of injury from sedentary related injuries to physical activity based injuries.

According to the 2016 statistics from the Entertainment Software Association compromising of 35 digital entertainment company members including Nintendo of America Inc., Microsoft Corporation and Sony Interactive Entertainment Inc., nearly 63% of American households play video games regularly (at least 3 h/week) with 65% of households owning a device used to play video games. The average game-playing US household consists of 1.7 gamers with an average age of 35 (Sales, Demographics and Usage Data Essential Facts about the Computer and Video Game Industry, Entertainment Software Association, Washington DC, April 2016). Statistics from Asian countries also point to high video game use, especially among adolescents. In Seoul, 36.2% of elementary school children spend >2 h/day playing video games. Nearly 8.7% of Singaporeans were found to be problem video gamers, spending excessive amounts of time playing video games. In Chinese adolescents, video gaming was one of the most time-consuming mediums among screen-related activities.[2] The term “eThrombosis” was conceived in 2001 to describe the increased risk of venous thromboembolism (VTE) from immobility caused by increased use of computers at both work and home.[3] Following on from this, there have been numerous case reports of vascular injuries associated with gaming including deep vein thromboses, pulmonary embolisms, and ruptured intraventricular arteriovenous malformations.
malformations (AVMs). More recently, following the advent of interactive video gaming where the gamer’s physical moves register with the game console to encourage sporting activity in a digital gaming environment on platforms such as the Nintendo Wii, there have been numerous musculoskeletal and nonosseous injuries reported in the literature. From a vascular injury context, this involved two internal carotid artery dissections suffered during physical participation in Wii sports games, both resulting in ischemic cerebrovascular injuries and permanent disability.

**Methods**

A literature review was performed between March 2016 and May 2017 on Medline and Pubmed in the English language. In Medline, the terms used included “Thrombosis” or “Artery” or “Vascular” or “ethrombosis” and “Video games” or “Wii” or “Nintendo” or “Wiitis.” This yielded 45 studies, of which six were relevant vascular injuries related to playing video games. A Pubmed search of the terms (“thrombosis” or “ethrombosis” or “vascular”) and (“video game” or “gaming” or “Wii” or “Nintendo” or “computer game”) yielded 83 studies, of which an additional five studies were found to be of relevance in addition to the above six identified studies. A total of 11 case reports reporting 12 cases of vascular injuries related to video gaming were identified.

**Results**

Table 1 shows details all pertinent characteristics of all VTE case reports associated with gaming.

In 89% of these case reports (n = 8), immobility was reported as the main risk factor identified for the ensuing

| Case        | Diagnosis                                                                 | Sex | Age | Risk factors (excluding immobility)                                                                 | Treatment and progress                                      |
|-------------|---------------------------------------------------------------------------|-----|-----|----------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| Beasley et al.[13] 2003 | Saddle PE. Preceding DVT symptoms and dyspnea                             | Male | 32  | Thrombophilia screen negative                                                                     | 6 months warfarin                                            |
| Ng et al.[3] 2003   | Superficial femoral vein DVT. Left calf pain and swelling                 | Male | 12  | Thrombophilia screen negative Positional factors: Legs flexed, calves beneath buttock                | No complications                                             |
| Lee[10] 2004       | Found deceased at home. Preceding syncopal episode. Saddle PE and bilateral popliteal vein DVTs | Male | 24  | No past or family history of thrombophilia                                                        | Anticoagulation and thrombolytic therapy                      |
| Chew[10] 2006      | Large right main pulmonary artery PE. Bilateral iliac vein DVTs. Shortness of breath and pleuritic chest pain One prior PE after gaming | Male | 16  | Thrombophilia screen negative No history of trauma                                                | Thrombolyis Suffered cardiac collapse requiring pulmonary embolectomy and IVC filter insertion |
| Phipps[11] 2008    | Right subclavian vein DVT. Prior arm swelling                             | Male | 33  | Thrombophilia screen negative Positional factors: Supine with arms vertically elevated compressing upper limb veins | Anticoagulation therapy                                      |
| Hayes et al.[12] 2013 | Large bilateral main pulmonary artery PEs. Worsening dyspnea and foot swelling | Male | 15  | Obesity Thrombophilia screen negative No recent trauma or travel                                  | Right heart strain despite thrombolysis requiring pulmonary thrombectomy |
| Chang et al.[13] 2013 | Left common iliac vein DVT. Left leg pain and swelling                   | Male | 31  | Thrombophilia screen negative                                                                      | Thrombolyis followed by enoxaparin                            |
| Braithwaite et al.[14] 2014 | Saddle PE. Two syncopal episodes and dyspnea                             | Male | 42  | Obesity Klinefelter’s                                                                              | Thrombolyis and 6 months anticoagulation                       |
| Brodmann et al[15] 2015 | Submassive right PE. Massive free floating DVT reaching from left pelvic veins to IVC | Female | 21  | Contraceptive pill Thrombophilia screen negative Positional factors: Legs flexed                    | IVC filter Urgent thrombectomy                                |

Overall there were eight cases of proven or suspected DVTs and six cases of significant PE, one of which was fatal. DVT: Deep vein thrombosis, PE: Pulmonary embolus, IVC: Inferior vena cava
Two consecutive 3 h periods developed sudden right orbital pain and left global hemiplegia. Imaging revealed an extensive intraventricular hemorrhage with a predominant right lateral ventricle. Two external ventricular drains were inserted, draining bloody cerebrospinal fluid. CT angiogram and arterial angiograms revealed an AVM fed by the anterior and posterior choroidal arteries at the right ventricle.

He later underwent stereotactic radio-surgery 3 months later after recovering to a GCS of 13. On the most recent reported follow-up, he had a GCS of 15 but with left-sided ataxia and hyperreflexia but normal sensory function. The authors remarked that during video gaming, the increased flow velocity of anterior, middle, and posterior cerebral arteries have been observed. This may result in an elevation of cerebral blood flow and increased perfusion pressure of the feeding artery, and subsequently, the increased pressure within the feeding artery can potentially contribute to an AVM hemorrhage.[5]

There have only been two reported cases of arterial dissection occurring during video gaming. Both patients were playing interactive high-intensity sports games on the Wii console system for at least one session of three consecutive hour periods. Both presented with focal neurology and diagnosed with ischemic cerebrovascular accidents secondary to internal carotid artery dissection. The first case occurred in a 47-year-old woman who while playing an interactive tennis game involving full physical activity for the previous three hours, felt sudden left neck severe pain with a headache followed by right hemiplegia and aphasia. She had a proximal internal carotid artery dissection occluding both this artery and middle cerebral artery. Despite thrombolysis and partial recanalization of the middle cerebral artery, had moderate disability at 3 months. A 14-year-old boy playing a physically intense interactive running video game for two consecutive 3 h periods developed sudden right orbital pain and left global hemiplegia. Imaging revealed a right intra petrous internal carotid, middle cerebral artery occlusion and stroke. Left sided neck pain and right hemiplegia.

**Intraventricular Arteriovenous Malformation Rupture and Internal Carotid Artery Dissection**

Table 2 details all pertinent characteristics of all case reports on ruptured intraventricular AVMs and internal carotid artery dissections associated with gaming.

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**Table 2: Summary of other vascular injuries associated with gaming**

| Case | Clinical condition and presentation | Sex | Age | Risk factors | Treatment and complications |
|------|-----------------------------------|-----|-----|--------------|-----------------------------|
| Chen et al.[3] 2011 | Intraventricular hemorrhage from ruptured grade three intraventricular AVM. Unresponsive episode with anisocoria, unilateral mydriasis and GCS five | Male | 32 | Nil identified | Two external ventricular drain Ongoing left sided ataxia and hyperreflexia. Sensory function normal |
| Faivre et al.[4] 2009 | Left internal carotid artery dissection causing internal carotid, middle cerebral artery occlusion and stroke. Left sided neck pain and right hemiplegia | Female | 12 | Three continuous hours of intense physical tennis interactive gaming | Thrombolysis Still dependent. Modified Rankin score of three |
| Faivre et al.[4] 2009 | Right internal carotid dissection. Right orbital pain and sudden left global hemiplegia | Male | 24 | Two consecutive 3 h sessions of running on spot on Wii balance board | Thrombolysis followed by anticoagulation Modified Rankin score three |

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Two cases of internal carotid artery dissections and an intracranial hemorrhage from a ruptured intraventricular AVM. AVM: Arterio-venous malformation, GCS: Glasgow Coma Score. Modified Rankin score: Scores degree of disability from 0 to 6, 0 equates to no symptoms, 6 equates to death.
carotid artery dissection with distal right middle cerebral artery dissection. Despite full recanalization of his middle cerebral artery following thrombolysis, he had disability at 3 months with a left hemiparesis.[7]

**Discussion**

Several reports elaborated on the prolonged position of the gamer before their acute VTE presentation. A 12-year-old boy with a left popliteal vein thrombus extending into the distal superficial femoral vein occurred after the child had been playing computer games for four consecutive hours with his legs flexed and calves underneath his buttocks for the whole duration of gaming.[8] Similarly, a 21-year-old woman who presented with right pleuritic chest pain and left leg swelling, later found to be a submassive right PE and a large thrombus involving the pelvic veins and the IVC, played Wii for 3 h in a “kneeling” position days prior with both feet underneath her buttocks.[15] Both had negative thromophilia screens. There have been several case reports where patients in prolonged positions of leg flexion or kneeling have suffered VTE episodes, some even fatal PEs. This included three cases of fatal PE following up to days of on-going kneeling during fasting prayers where both immobility, as well as dehydration, likely attributed to VTE.[18] Similarly, there are two cases in the literature where prolonged kneeling while wearing knee pads were associated with a subsequent DVT, the authors attributing the pathology to a combination of venous stasis and extrinsic tight pad compression causing vascular endothelial trauma.[19,20]

The only case report of an upper limb DVT (right axillary and subclavian vein) associated with gaming occurred in a 33-year-old who was playing supine with his portable game console close to his eyes with his arms raised vertically for 3 continuous hours, only stopping momentary due to paraesthesia. The authors remarked that the prolonged raised arm position caused compression of the veins at the costoclavicular space level. As the arm action becomes repetitive and prolonged, it may have led to endothelial damage that contributed to venous thrombosis formation of the upper limb, known as “Paget-Schroetter Syndrome.”[11]

The World Health Organization has recommendations on reducing the risk of DVT on long haul flights including walking around the cabin at least every 2–3 h. They acknowledged that risk of DVT is higher if passengers were older or had other risk factors associated with Virchow’s triad (International travel and health, World Health Organisation, Geneva, 2016). However, in some of the above cases associated with gaming above, otherwise young, healthy patients with no thromophilia or other known VTE risk factors developed DVT or a significant PE after only 3 h of immobility. Other risk factors which may contribute to VTE in gamers include dehydration from prolonged gaming whether that involves neglecting their thirst reflex or by consuming beverages or food high in sugar, caffeine, or salt such as coffee or energy drinks. In addition, extreme gamers (described as 50 h/week playing time) are more likely to lead a sedentary lifestyle and be overweight or obese.

From all of the above, our recommendations would be for gamers to not remain immobile for more than one continuous hour, to take at least a 5 min break between each hour of gaming to actively mobilize and perform ankle flexion and extension exercises. Gamers should also be adequately hydrated with water and not high sugar-containing beverages. In addition, we recommend that gamers not be in the same position for the whole one hour sitting, especially if that sitting is causing compression of their deep venous system, especially legs flexed and claves compressed or arms raised vertically while in a supine position. Interactive video games such as Wii may be an alternative to conventional gaming and may reduce the risk of immobility associated VTE. However, these physically interactive consoles do have their own risks as discussed below in relation to vascular injuries as well as a host of traumatic injuries leading to soft tissue, bony and even serious organ injury requiring emergency surgery.[14]

Contrary to video gaming associated immobility leading to VTE, Nintendo Wii promotes interactive gaming where the user is consistently required to physically move to continue playing the array of largely sporting games, replicating actions required in real sports. Not only does this promote physical activity and its health-related benefits including reducing the problems associated with immobility, Wii may have potential in rehabilitation programs (including in poststroke patients) as well as improving laparoscopic skills for surgical doctors.[21,22] However, there have been documented reports of Wii related injuries, especially musculoskeletal trauma due to the physically nature of the gaming console in a population that may not be optimally prepared for the tasks involved. A 2015 systematic review of Nintendo Wii trauma-related injuries revealed 11 published case reports of injuries related to Wii ranging from fractures to nonosseous trauma and overuse injuries.[9]

In the two carotid arterial dissection cases, there are interesting analyses of the potential mechanisms of injury and how they may be related to physically intensive interactive games. This may continue to present a significant problem for users now and in the future. In the tennis game, because the user is not holding an actual tennis racket and not encountering an opposing force caused by hitting an incoming ball, there is less overall opposing force encountered at maximal arm exertion in the virtual game compared to real tennis. This can result in greater torsion at the cervical level which probably contributed to her carotid dissection. Virtual games may allow the average person to perform unfamiliarly intensive physical activity without any additional physical and balancing limitations that are encountered in real sporting activities. Unopposed intense physical movements without the constraining physical forces encountered in real sporting activities are thought to have significantly contributed to dissection in the above two, although rare cases, resulting in significant permanent
injuries.\(^7\) Similar findings of reduced co-ordination or physical control that would normally safeguard the participant from more serious physical injuries (inability to mimic exact real sporting situations as exemplified above, input from teammates and coaches) during sporting activities are increasingly being found to contribute to injuries from virtual gaming, especially with regards to soft tissue and bone injuries.\(^6\)

Regarding Wii and other interactive video games which may involve intense physical activity, our recommendations include for gamers to balance their physical ability with the requirements of the game and not to exert full physical effort, especially when the game requires sudden changes in momentum or sudden movements of the head, neck or limbs. As the virtual game does not completely represent the physical dynamics of the real sport it is mimicking, exerting full force movements while interactively gaming may actually cause serious and permanently disabling injuries as in the cases of internal carotid artery dissection as well as other nonossesous and musculoskeletal injuries described in the reviews mentioned above. Granted the rarity of these published case reports in the context of greater than 100 million Wii consoles sold worldwide, the injuries do take place, are likely under-reported and can cause severe and permanent morbidity.

**Conclusion**

There are numerous reports of serious gaming-related injuries in the literature including vascular related injuries. The 12 vascular reported cases discussed in this review were all very significant, some resulting in life-threatening and fatal events, with several resulting in permanent disability. By far, the most prevalent vascular related gaming injury is associated with immobility causing VTE. In the reported literature, the only risk factor mentioned in most of the nine reports was immobility. Without a second VTE risk factor, this is a largely unusual observation, especially in a relatively younger population. This is exceptionally important in the context of generating larger thromb in the iliac veins and especially so if such thrombi dislodge and cause large pulmonary emboli. However, with changing technology, new problems arise. The advent of interactive gaming such as the Nintendo Wii console which promotes healthy and fun physical gaming has many positive implications on the user whether it promotes physical activity or in specific demographics such as patients requiring physical and neurological rehabilitation and surgical doctors improving their laparoscopic skills. They most certainly reduce immobility and reduce the numerous and significant issues associated with immobility, although they do not entirely eliminate VTE risks, as described in the latest case report on the gamer suffering a large IVC thrombus after playing Wii.

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**Conflicts of interest**

There are no conflicts of interest.

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