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Article

A new Algorithm for Detecting Clinical High Risk of Psychosis in Adolescents

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ABSTRACT

Background: The delimitation of the clinical high risk of psychosis (CHRp) is characterized by the wide variety of symptoms assessed from different approaches and the difficulty in detecting clinical stages that are a long way from the onset of psychosis. This study aimed to create a systematic procedure for an effective and accurate early detection of CHRp in educational settings. **Method:** A representative sample of 1,824 adolescents (average age, 15.79; 53.8%, women) was used to develop an online assessment system and a new 3-track, 3-level algorithm that combines symptoms of the main risk approaches: ultra-high risk (UHR), basic symptoms (BS), and anomalies in the subjective self-experience (ASE) with functional deficit. **Results:** The acceptability and feasibility of the online screening system were confirmed by the data. Of the total participants, 68 (3.7%) were identified as high-risk and 417 (22.9%) were identified as moderate, which also supports the functionality of the proposed algorithm. **Conclusions:** The system indicates a dynamic model of progression of the different symptoms in the early stages of psychosis, and it may constitute a first line of identification for severe mental disorders in young people in the earliest stages, allowing application of initial preventive measures.

Un Nuevo Algoritmo para la Detección del Alto Riesgo Clínico de Psicosis en Adolescentes

Palabras clave:
Riesgo de psicosis
Adolescencia
Reclutamiento online
Algoritmo
Prevención temprana

RESUMEN

Antecedentes: La delimitación del alto riesgo clínico de psicosis (CHRp, por sus siglas en inglés) se caracteriza por la gran variedad de síntomas evaluados desde diferentes enfoques y la dificultad que existe para detectar los estadios clínicos más alejados del inicio de la psicosis. Este estudio tiene como objetivo la creación de un procedimiento sistemático para una detección temprana eficaz y precisa del CHRp en entornos educativos. **Método:** A partir de una muestra representativa de 1.824 adolescentes (edad, media= 15,79 años; 53,8%, mujeres) se ha desarrollado un sistema de evaluación online y un algoritmo de tres vías y tres niveles de riesgo que combina los síntomas de los principales enfoques de riesgo: ultra-alto riesgo (UHR), síntomas básicos (SB) y anomalías en la autoexperiencia subjetiva (ASE), además del déficit funcional. **Resultados:** A la luz de los datos obtenidos se han confirmado la aceptabilidad y viabilidad del sistema de cribado online. Del total de participantes, 68 (3,7%) fueron identificados como de alto riesgo y 417 (22,9%) como de riesgo moderado, lo que también avala la funcionalidad del algoritmo propuesto. **Conclusiones:** El sistema apoya la existencia de un modelo dinámico de progresión de los diferentes síntomas en las primeras etapas de la psicosis, y puede constituir una primera línea de identificación de los trastornos mentales graves en los jóvenes en las etapas más tempranas, de cara a la aplicación de las medidas preventivas iniciales.

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Research has shown that a considerable number of young people are at risk of developing psychosis throughout their lives, with serious consequences on personal, educational, family, social, economic, and health levels (Catalan et al., 2020; Fusar-Poli et al., 2020a; Malla & McGorry, 2019). Implementing detection and prevention programs for psychosis in teens therefore offers the most cost-effective option by providing life-long benefits to those affected and their families (Campion et al., 2019; Chong et al., 2016; Fusar-Poli et al., 2020b). A combination of a rapid, rigorous, and updated screening procedure aimed at detecting individuals considered to be at risk of psychosis according to early detection approaches, and the immediate referral of these cases to specialized services, will constitute the most efficient and comprehensive procedure for early prevention of psychosis in young people.

Research has also shown that the delimitation of the CHRp or "at-risk mental state of psychosis" is characterized by the wide variety of symptoms assessed from different approaches to early detection (Ramella Carvaro & Raballo, 2014; Sanfelici et al., 2020). These approaches include: a) the ultra-high risk criteria (UHR), focusing on the detection of so-called attenuated psychotic symptoms or "positive" symptoms, referring to the presence of anomalous experiences, such as depersonalization, suspicious or magical thinking below the psychosis threshold; b) the basic symptoms perspective (BS), initially described from a phenomenological approach by Huber and Gross (1989), consisting of perceived subjective alterations of different domains such as perception, sustained attention, cognitive processing, and language, which can be present in the prodromal phase as part of the earliest manifestations of psychosis (Miret et al., 2016); and, more recently c) the non-psychotic anomalies in the subjective self-experience (ASE) approach, grouping symptoms, such as hyperreflexivity (Pérez-Álvarez, 2016; Sass & Parnas, 2003) or exaggerated self-awareness, with prospective support as risk markers and central features of psychotic disorders (Koren et al., 2020; Værnes et al., 2019).

These different approaches to CHRp result in disparity in the percentages of individuals detected to be at risk, depending on the risk criteria chosen, the screening tool used, and the sample setting. A recent meta-analysis of factors associated with the onset of psychosis in individuals at CHRp (Oliver et al., 2020) determines that global functioning shows evidence suggesting an association with transition to psychosis, which supports the inclusion of this domain in early detection procedures. Moreover, numerous assessment instruments have been developed according to the three approaches.

A preliminary literature review for the present study, limited to studies from 2015 onwards and following standardized data extraction by two independent reviewers (M.P. and O.V-F), reported a big percentage window of high-risk cases with detection rates ranging from 0.9% to 80% depending on the approach, assessment tool, and sample included in the study, with the lowest rates being usually around 10-15% (Chen et al., 2016; Dolphin et al., 2015; Fonseca-Pedrero et al., 2016a). According to this review, the risk of psychosis is 23.8%, consistent with the rates reported in recent meta-analysis studies (Catalan et al., 2020; Fusar-Poli et al., 2020a). Note also that studies that report high-risk percentages are not usually conducted with samples of only adolescents (up to the age of 19), but often include young adults (i.e. Flückiger et al. 2019; Schultze-Lutter et al., 2020), which increases the probability of transition rates.

The present study aimed to create a systematic procedure for the effective and accurate early detection of CHRp in educational settings in the context of our *Psychosis Prevention Program* (P3; http://www.p3-info.es); integrating the main three risk approaches (UHR, BS, and ASE) and combining all three with the presence of functional deficits. We established two main research objectives: 1) to create a systematic online screening procedure, adapting different brief and recent psychometric assessment instruments of psychological risk characteristics in adolescents to be delivered through our *Virtual Laboratory* in P3 (http://www.p3-info.es); and 2) to develop and test the accuracy of a novel algorithm with three tracks (following the main approaches to risk plus global functioning) in identifying individuals at risk of psychosis in a representative sample of adolescents. In line with these objectives, we hypothesized that: i) the online screening system would be acceptable and feasible for the selected sample of adolescents; ii) the proposed algorithm would identify and distinguish different groups of risk individuals according to combined risk levels of the three tracks; iii) the detected percentage of adolescents at CHRp would be lower than the lowest rates of 10-15% reported in recent studies, thanks to the forecast and accuracy provided by this algorithm and given the average age of the sample; iv) following this algorithm, a greater number of moderate risk adolescents will be also detected, similar to the 23% average found in recent studies.

Method

Participants

The population of interest consisted of students born between 2000 and 2003, who were enrolled in educational centers in the Principality of Asturias. A representative sample of 1,824 adolescents was obtained, following stratification and probability procedures consisting of dividing the entire population into different subgroups or disaggregated strata and obtaining a subsample in each of them. In addition, a two-stage sampling was performed, first considering the selection of centers (Stratum 1: public centers, Stratum 2: private subsidized centers) and then the selection of the student body (sub-samples of middle school, high school, and vocational training).

Instruments

The Oviedo Schizotypy Assessment Questionnaire-Abbreviated (ESQUIZO-Q-A; Fonseca-Pedrero et al., 2010) is the short version of a self-report questionnaire for assessing schizotypal traits in adolescents. ESQUIZO-Q-A comprises a total of 23 items with 5 categories distributed across 3 empirically derived subscales: Reality Distortion, Anhedonia, and Interpersonal Disorganization. Its internal consistency levels range from .67 to .71, and it has different sources of validity (Fonseca-Pedrero et al., 2010; Fonseca-Pedrero et al., 2011). The provided cut-off points were dichotomized as follows: 0 = "no symptoms" (if scores < 50th percentile on any of the three subscales of

ESQUIZO-Q-A) and 1 = "moderate-severe symptoms" (if all three scores > 50th percentile).

Prodromal Questionnaire-Brief Version (PQ-B; Loewy et al., 2011; Spanish validation by our group (Fonseca-Pedrero et al., 2016b)) consists of 21 true/false items assessing the presence and frequency of prodromal psychotic experiences in the last month. It also includes a sub-section about the severity of the interference and distress from these experiences on a 5-point Likert scale. The internal consistency of the PQ-B total score was 0.93 (Fonseca-Pedrero et al., 2016b). The following cut-off scores were used: higher than 6 points on the *Total* score and 29 points or higher on the *Distress* score (Kline et al., 2015).

Global Functioning: Social and Global Functioning: Role (GF: Social & GF: Role; Cornblatt et al., 2007). The GF Social scale assesses the quantity and quality of peer and family relationships. The GF Role scale anchor points adapted to adolescents, refer to performance in school, in terms of the level of support required. In consultation with the measure's originator, two short adapted versions were used for the present study. For both scales, scores range from 1 (extreme dysfunction) to 10 (superior functioning). Based on the original scales, the cut-off point to determine "major impairment" was < 5.

Frankfurt-Pamplona Subjective Experience Scale (EEFP; Cuesta et al., 1995; short version of the Frankfurt Complaint Questionnaire, FCQ; Süllwold, 1986), consists of 18 items, aiming to assess subtle anomalous subjective experiences in attenuated psychosis (e.g., difficulties in attention, memory, perception). This measure has shown high internal consistency (Cronbach's alpha= 0.91) and displays convergent validity (Raballo et al., 2007; Stip et al., 2003). Due to the lack of cut-off points, extreme values of the 90th percentile were considered here for presence of BS.

Self-Experience Lifetime Frequency Scale (SELF; Heering et al., 2016, version translated and adapted to Spanish following international guidelines (Muñiz et al., 2013)). This 12-item scale was designed to screen for symptoms of depersonalization and covers a wide range of experiences of self-disturbance. Individuals are asked to report on a 5-point Likert scale about the lifetime frequency and level of burden of these symptoms. The original factorial structure analysis yielded two components: *Disturbed Self-awareness and Symptoms of Depersonalization,* both with good internal consistency: Cronbach's α = 0.88 and 0.79, respectively. For this study, at least 3 items scoring > 3 in *Frequency* and >2 in associated *Distress* were required to consider the presence of self-disorder.

Oviedo Infrequency Response Scale-Revised (INF-OV; Fonseca-Pedrero et al., 2009). The INF-OV was developed to detect participants who respond in an untruthful, random o pseudo-random way to the used self-reports. Designed also as a self-report type assessment tool, INF-OV comprises 12 likert-type statements with five categories. Adolescents scoring ≥ three items of the INF- OV incorrectly are eliminated from the final sample. The INF-OV has been used in previous studies (Fonseca-Pedrero et al., 2011; Fonseca-Pedrero et al., 2016b). A revised version was used in this study, where two items were removed after finding that they didn't discriminate.

[For complementary survey measures used, see Table 1].

Procedure

Cross-sectional design, using an online platform to deliver the symptom screening. This study was conducted between March 2018 and May 2019. The Education Office of the Government of the Principality of Asturias and the university's Research Ethics Committee approved it. It received the support of the Mental Health Unit of the local Department of Health. The data file was registered in the General Data Protection Register of the Spanish Data Protection Agency.

Initial contact with schools was made by telephone and email, via the school principal or the counsellor. A total of 50 schools were contacted, 37 of which agreed to take part in the study. Since many of the participants were minors, written parental consent was required. Online questionnaires were administered via computer or tablet, by school-class, with 3 researchers in charge. Adolescents were informed in writing and orally of the voluntariness of participation and the confidentiality of their answers. No compensation was given for participating in the study.

Data analysis

Descriptive statistics on socio-demographic and environmental characteristics for the entire sample were expressed as frequencies and percentages from different available survey instruments (see Table 1).

Algorithm development: based on the data from the most used clinical approaches to psychosis risk, the algorithm consists of a combination of the cut-off points indicated in the original scales or, alternatively, weighted scores based on extreme values. The designed algorithm aimed to identify 3 risk tracks considering the severity of the "pre-psychotic" symptomatology reported in the screening: (T^1) *Track 1 ≈ UHR + low GF (Global Functioning)*, which combines 3 Schizotypy subscales (Reality Distortion, Anhedonia, and Interpersonal Disorganization) + the 2 Prodromal subscales (PQ-B, Frequency and Distress) + the 2 Global Functioning scales (GF: Social and GF: Role); (T^2): *Track 2 ≈ BS + low GF*, which combines the Basic Symptoms Scale (EEFP) + the 2 Global Functioning scales (GF: Social and GF: Role); and (T^3) Track 3 ≈ ASE + low GF, combining the SELF scale + the 2 Global Functioning scales (GF: Social and GF: Role). The three resultant variables were broken down into 3 risk levels, thus: Level 2 = High risk (above the cut-off point in all the included scales of each track), Level 1 = Moderate risk (above the cut-off point in one of the included measures -in two measures for T1-) and Level 0 = No or low risk (below the cut-off point in all the scales; -may exceed the cut-off point in just one of them for T1-) (for a more detailed explanation see also Table 2). The algorithm could be synthesized in the following formula:

(T^1 ≈ UHR + low GF) OR (T^2 ≈ BS + low GF) OR (T^3 ≈ ASE + low GF) = AT RISK MENTAL STATE (2/1/0)

The algorithm also allows us to establish 6 high-risk groups by combining the different risk levels (high/moderate) of the three tracks (Table 3). Classification is made depending on

scoring 2 on at least one track, track 1 being the most sensitive one (higher weight). Group 1 (highest risk) includes all those who scored 2 on all three tracks; Groups 2 and 3 include those who scored 2 on two tracks, and Groups 4 to 6, include those with the lowest high risk of psychosis, who scored 2 on just one track.

Data analyses were performed with XLSTAT 2020.1.3 Basic+ (Addinsoft, 2019) and the SPSS 20.0 statistical package for Mac OS X (IBM Corp Released, 2011).

Results

Socio-demographic and environmental characteristics of the sample:

The general characteristics of the study population are presented in Table 1. After removing 200 participants via the *Oviedo Infrequency Response Scale* (INF-OV) (Fonseca-Pedrero et al., 2009) or due to being out of age range, a total of 1,824 adolescents were included in the study. Of these, 843 (46.2%) were males and 981 (53.8%) females, recruited from 123 classrooms, with an average age of 15.79 (SD=1.25). The largest concentration of participants was 14-17 at the time of assessment (91.8% of the total). Main demographic results showed: a) 6.4% declared that they were immigrants; b) 3.4% were from families living in deprivation; c) 35% reported having experienced at least one distressing traumatic event; d) 9.6% of the sample reported having used cannabis 1 or 2 times in the last three months, and 4.6% reported using it *daily or almost daily*; and e) 4.5% of the students had failed the previous academic year.

Algorithm results:

Sixty-eight participants (3.7%) were identified as high-risk, having scored 2 on one (or more) of the three risk tracks. A total of 417 (22.9%) were identified as moderate-risk, having scored 1 on one of the three tracks. Analyses by tracks showed that 44 of the 68 high-risk participants were detected by Track 1, which means that these individuals would have scored above the cut-off point in the three included scales [Schizotypy AND Prodromes AND Low Global Functioning]. For more information on the risk levels of tracks and the specific percentages obtained with the algorithm, see Table 2.

Analyses by high-risk groups (Table 3) showed that 8 of the 68 participants (0.4% of total sample) scored as high risk (point 2) on all three tracks (Group 1). Twenty-three (1.3%) participants scored as high risk (point 2) on two tracks: those who scored 2 on Track 1 and also scored 2 on another track also obtained a moderate-risk score (point 1) on the remaining track (Tracks 2 or 3); these participants were categorized as Group 2. Those who scored 2 on Track 2 and Track 3 were low risk/non-risk (point 0) on Track 1, accounting for Group 3 (lower level of risk). The rest (N=37, 2.0% of the total sample) were in Groups 4 to 6, which included participants who scored 2 on just one track. It is important to note that all cases that were classified as high-risk (point 2) by Track 1 were of moderate risk on the other two tracks, but the behavior of the algorithm was different for Track 2 and Track 3: most of the cases categorized as high risk (point 2) on Track 2 scored 1 (moderate risk) on Track 3, and vice versa, but they obtained a 0 (low risk) for Track 1 (UHR track).

Of the 417 (22.9%) identified as moderate risk (point 1) by the algorithm, 29 (1.6% of the total sample) were of moderate risk (point 1) in all three tracks. Of those who scored 1 (moderate risk) in two of the three tracks, most were in Tracks 2 and 3 (105 cases; 5.8%), with 0 (low risk) being obtained for Track 1 (UHR). Mirroring the results of the high-risk groups, Track 1 seemed to be more restrictive in identifying moderate-risk cases. Finally, the remaining 244 (13.4% of the total sample) were of moderate risk only on one track.

Table 1.
Socio-demographic and environmental characteristics of included participants.

		Total sample (N=1,824)	
		N	%
Sex	Male	843	46.2
	Female	981	53.8
Age	Mean: 15		
	SD: 1,17		
	Range: 14-19		
Educational stage	Middle school	1,013	55.5
	High school	739	40.5
	Vocational education	72	4
Nationality	Spanish	1709	93.7
	Latin-American	54	3
	European (non-Spanish)	24	1.3
	Dual (+Spanish)	20	1.1
	Non-European	15	0.9
Family affluence[1]	Low	57	3.4
	Medium	755	45.7
	High	841	50.9
Parents' nationality[1]	Both Spanish	1,446	87.5
	One Spanish	88	5.3
	Both non-Spanish	119	7.2
Traumatic experience/s[2]	No/Yes2	982/842	53.8/46.2
	Associated Distress		
	Mean: 1.12		
	SD: 1,25		
	Range: 0-4		
Substance use[3]	Cannabis (No/Yes)	1,457/367	79.9/20.1
	Tobacco4 (No/Yes)	851/791	51.8/48.2
	OH4 (No/Yes)	1,104/538	67.2/32.8
	Others4 (No/Yes)	1,569/74	95.6/4.5
Any Fail in the preceding school period	Yes	727	39.8
	No	926	50.8
Any Fail in the preceding school period	Outstanding	321	17.6
	Above average	622	34.1
	Good	390	21.4
	Pass	238	13.0
	Fail	82	4.5

Note: 1: Obtained with the *Family Affluence Scale* (FAS; Boyce et al, 2006; Fismen et al., 2016), missing cases n=171 (9.4%); 2: Yes = point > 1 (any traumatic event) by the *Screening of Early Traumatic Experiences in Patients with Severe Mental Illness* (ExpTra-S; Paino et al., 2020); 3: Yes = point > 1 (any consumption in the last three months) in the *Alcohol, Smoking and Substance Involvement Screening Test (WHO-ASSIST V3.0*; Newcombe et al., 2005; WHO, 2010); 4: Missing cases n=182 (1%).

Table 2.
Frequencies and percentages of participants detected at risk of psychosis by the three algorithm tracks.

	Level 2 (High Risk)	Level 1 (Moderate Risk)	Level 0 (Low Risk)
	N (%)	N (%)	N (%)
Track 1 (T^1)	44 (2.4%)	252 (13.8%)	1,491 (81.7%)
Track 2 (T^2)	37 (2.0%)	244 (13.4%)	1,500 (82.2%)
Track 3 (T^3)	26 (1.4%)	236 (12.9%)	1,512 (82.9%)

Note: Track 1 ≈ UHR + low GF (Global Functioning) (Risk levels= 2: above the cut-off point in the three included scales; 1: above the cut-off point in [Schizotypy AND low GF] OR [Schizotypy AND Prodromes] OR [Prodromes AND low GF]; 0: below the cut-off point in all the scales OR exceeding the cut-off point in just one of them-; Track 2 ≈ BS + low GF (Risk levels = 2: above the cut-off point in [Basic Symptoms Scale AND GF Social AND GF Role]; 1 = above the cut-off point in one of the three included scales; 0 = below the cut-off point in all the scales). Track 3 ≈ ASE + low GF (Risk levels = 2: above the cut-off point in [SELF scale "anomalous self-experience" AND GF Social AND GF Role]; 1 = above the cut-off point in one of the three included scales; 0 = no alteration in any of them).
Missing cases Track 1= 37 (2.0%); Track 2= 43 (2.4%); Track 3=50 (2.7%)

Table 3.
Identified high-risk groups according to combined risk levels of the three tracks.

Combined Risk Group	N	%
Group 1 (T1 =2* AND T2 =2 AND T3=2)	8	0.4
Group 2 (T1 =2 AND T2 =2 AND T3=1) OR (T1 =2 AND T2 =1 AND T3=2)	19	1.0
Group 3 (T1 =0 AND T2 =2 AND T3=2)	4	0.2
Group 4 (T1 =2 AND T2 =1 AND T3=1)	17	0.9
Group 5 (T1 =1 AND T2 =2 AND T3=1) OR (T1 =1 AND T2 =1 AND T3=2)	3	0.2
Group 6 (T1 =0 AND T2 =2 AND T3 =1) OR (T1 =0 AND T2 =1 AND T3 =2)	17	0.9
TOTAL	68	3.7

Note: T1 = Track 1 ≈ UHR + low GF; T2 = Track 2 ≈ BS + low GF; T3 = Track 3 ≈ ASE + low GF; *Risk levels: 2= high risk; 1= moderate risk; 0= low risk. Each group is exclusive.

Discussion

The purpose of this study was the creation -within our *P3 program*- of a systematic procedure for effective early risk detection in school settings, incorporating the new technological (online assessment), conceptual (integration of proved risk approaches), and methodological (algorithmic) developments. The acceptability and feasibility of the developed online screening system (hypothesis 1) have been confirmed in the light of two criteria: the participation of high schools and the reliability and sufficiency of all the data obtained from the adolescents. A total of 37 secondary schools of the 50 invited to participate agreed to take part in the study, including 123 classes, and covering the three school types and the three school stages. This has resulted in more than 2,000 participants being recruited and assessed, confirming the viability of our system as a first line screening method for mental disorders in young people. The functionality of the proposed algorithm has also been proved (hypothesis 2), as it appears useful for detecting adolescents with high or moderate risk of psychosis, considering three different tracks based on the most used clinical approaches to psychosis risk. To our knowledge, this is the first algorithm that integrates the three main approaches to at-risk mental state in combination with global functioning. It provides a risk profile based on the combination of the risk scores obtained (2, 1, 0) based on each track, and it reinforces the idea that although the three approaches to the risk of psychosis may appear to be in conflict, they are not necessarily mutually exclusive.

The study of mental states at high risk for the development of severe mental disorders has mainly been conducted in young people presenting active, distressing symptomatology and/or seeking help. They are assessed using long clinical interviews for detection (Addington, 2020; McGorry et al., 2006). However, CHRp states are difficult to detect for two main reasons: (1) young people who present attenuated psychotic experiences are less likely to look for help due to stigma, and (2) clinicians are less familiar with these experiences (in comparison with, for example, anxiety or depression). This severely limits access to mental health services for these individuals and hinders interventions that could prevent the development of disorders, so a more proactive search to identify them is needed. The implementation of detection and identification procedures based on self-reports, easily accessible and available online (Alfonsson et al., 2014; van Ballegooijen et al., 2016), can be very useful in detecting young people at risk of severe mental health problems, helping to eliminate barriers.

The three levels of risk encountered in the present study coincide with the three initial stages of the staging model suggested by McGorry and colleagues for teenage populations (0. No symptoms -in first-degree teenage relatives of probands-, 1a. non-specific symptoms, 1b. UHR, moderate with functional decline) (Carrión et al., 2017; McGorry et al., 2006) and verified in the PROCAN study (*Adolescent Mental Health: Canadian Psychiatric Risk and Outcome*, Addington et al., 2019; 2020). There is an additional advantage of our research: the aforementioned studies focus on clinically established and help-seeking young people, while the present research focuses on young people from the general population. The fact that both populations reflect the same stages confirms the existence of a progression in the presence and intensity of different symptomatology (UHR, BS, ASE) in the very early phases of psychosis.

The exploration of the algorithm's behavior revealed that the concurrence between attenuated psychotic symptomatology (UHR) and self-disorders is consistent with the results obtained in studies in help-seeking adolescents (Koren et al., 2013; Raballo et al., 2018) and adolescents from the general population (Koren et al., 2016). In these studies, ASE and UHR evolve in intensity and presence, being more present and active in clinical samples that seek help and less in community samples, which confirms the gradient of severity throughout the biography of individuals. This also confirms that both types of symptoms can be perfectly integrated to achieve a better detection of prodromal states of psychosis and to fine-tune their transition risk (Nelson et al., 2021). Concurrence is also found among studies that have combined clinical UHR and basic symptoms (Schultze-Lutter et al., 2020), obtaining more accurate predictive results when the two approaches are combined.

The third and fourth hypotheses have also been confirmed, as a low percentage of high-risk adolescents (3.7%) was detected as expected, in comparison with the moderate risk group (22.9%), when the calculation of the risk was based on the combined scores of tracks. The high-risk percentage found in our study is similar to prevalence rates of meta-analytical studies focused on psychotic-

like experiences (PLEs) in adolescents (reported to average around 7-9%) (Healy et al., 2019; Kelleher et al., 2012). Our percentage of moderate risk is more consistent with the average rates of adolescents at CHRp detected by considering other different criteria such as attenuated psychotic symptoms, brief-limited-intermittent psychotic symptoms, or genetic risk and deterioration syndrome (Catalan et al., 2020; Fusar-Poli et al., 2020a) as well as in our present revision.

The emerging question then is to propose an explanatory model for the process of psychosis risk, taking into account algorithm measures and results. Following the parallelism between the present results and the clinical staging model, one proposal could be a dynamic process of increased risk of psychosis rather than a hierarchical one (Flückiger et al., 2019; Schultze-Lutter et al., 2018; Wright et al., 2018). In line with recent proposals (Nelson et al., 2017; Thompson & Broome, 2020), the detailed results from the application of our algorithm indicate a pattern where cases detected as high risk by Track 1 (UHR track) are also detected as high or moderate risk on the other two tracks (BS and ASE tracks), but not vice versa. This means that the combination of UHR symptoms with global functional deficit (Track 1) could be more restrictive and accurate in identifying high-risk cases than the use of indicators based only on BS or ASE, even if combined with low functioning indexes. These results are also in line with those found in a recent meta-analysis by Oliver et al. (2020). This comprehensive review points out the *highly suggestive evidence* for an association of two factors with the onset of psychosis in individuals of clinical high risk: attenuated positive psychotic symptoms and global functioning (i.e., Track 1 in the present study). Based on all of the above, and considering that the average period of time between detection of BS or ASE and the onset of psychosis is longer than that between UHR detection and first episode (Ramella Carvaro & Raballo, 2014; Ruhrmann, 2010), it appears that BS and ASE (Tracks 2 and 3 in the present study) are more appropriate for the early detection of the more distal prodromal states or moderate risk, compared to the more proximal or high-risk ones indexed by UHR criteria or Track 1.

Some limitations should be considered when interpreting our results. Firstly, the sample included exclusively high school students, potentially including but not clearly identifying help-seeking adolescents. Secondly, there are inherent limitations of the use of self-reported measures (Fan et al., 2006) to perform the proposed algorithm. Thirdly, and according to the psychosis proneness-persistence-impairment model, the determining of psychosis risk in these early stages would involve the interaction of multiple risk factors (Linscott & van Os, 2013) such as late environmental disruptions (i.e., early traumatic experiences, cannabis use, academic performance, immigration, or socio-economic status) (Davis et al., 2016; Mednick et al., 1998). Although some of these variables have been collected (see Table 1), they were not included when running the algorithm. Lastly, there is no follow-up time point to test rates of transition to psychosis in subjects detected as being at risk.

Clinical implications and future research: From here, a longitudinal design is proposed to follow up on participants identified as being at risk and invite them to participate in early prevention programs when necessary. The proposed algorithm may allow us to establish preventive measures adapted to the different levels of risk, providing particular clinical attention to adolescents with the highest levels (high-risk groups 1 and 2). For these cases, the recommendation would be to refer them directly to mental health services. Those falling into the next high-risk group (group 3) could be called in for a more thorough assessment, including close monitoring of early signs. The lowest high-risk groups (4 to 6), could be followed up by using telephone interviews or internet monitoring. Finally, those detected as "moderate risk" could be scheduled for longer term follow-ups and re-assessment via our online screening program. In order to further validate our integrative approach and proposed algorithm, the present study should be replicated in other non-Spanish samples.

In conclusion, our results show that the detection of risk for psychosis based on unitary approaches is far from satisfactory and in need of reconceptualization. The incorporation of new technological, methodological, and substantive developments for the rapid detection of risk cases can provide a cost-effective prevention alternative. In addition, the comparison of the validity of the three main approaches to risk and their attempt at integration may be of great value in enriching the current operational criteria and in trying to define a better perspective for approaching the risk of psychosis in the adolescent population. The current findings can inform the refinement and increase the accuracy of predictive models in this field.

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